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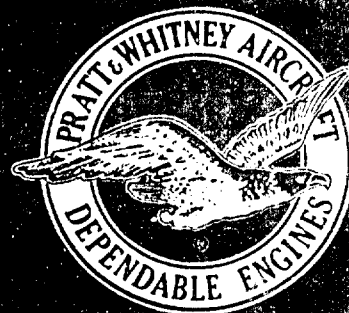
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**Pratt & Whitney Aircraft** DIVISION OF UNITED AIRCRAFT CORPORATION

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WEST PALM BEACH, FLORIDA

September 2, 1966

Major General J. C. Maxwell  
Federal Aviation Agency  
800 Independence Avenue, S. W.  
Washington, D. C. 20553

Attention: SS-30

Dear General Maxwell:

In response to the Federal Aviation Agency's Request for Proposal dated June 30, 1966, we transmit herewith our proposal for the engine portion of Phase III of the Supersonic Transport Development Program. We believe our proposal is completely responsive to the Request for Proposal. It covers the development of the JTF17A-21 augmented turbofan engine, the delivery of ground test and flight test prototype engines, and their support through 100 hours of prototype aircraft flight testing. This proposal is not subject to withdrawal or change by us if accepted by the Government by January 1, 1967, and we shall be pleased to hold it open until that time.

The 61,000 lb. thrust (sea level static take-off rating) augmented turbofan engine described in this proposal is substantially the same engine being demonstrated currently in our Phase II-C program. During the Phase II-C testing of this engine, the mechanical concept has been proved practical; the engine has been operated successfully at Mach 2.7 and 65,000 feet altitude; the main and duct burner designs have been proved satisfactory; the turbine cooling approach has been confirmed by operation at full rated turbine temperature; and the engine weight estimate has been validated. The majority of the Phase II-C contract goals have already been met, and we have accumulated over 86 hours total full scale engine time on two demonstrator engines. It now appears that all of the Phase II-C contract requirements will be completed ahead of schedule and within the contract cost.

The JTF17 program schedule, which meets either Lockheed's or Boeing's requirements, includes the following important milestones:

Flight Test Status (FTS) Completion	June 1969
Deliver First Flight Prototype	July 1969
Engine Certification	December 1971
Deliver First Production Engine	January 1972

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Major General J. C. Maxwell

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September 2, 1966

The engine development program up to engine certification will include approximately 14,500 hours of full-scale engine development testing, about one-half of which will be conducted at simulated high Mach number environmental conditions.

The engine development program will continue to be conducted at Pratt & Whitney Aircraft's Florida Research and Development Center in order to take advantage of the specialized engineering background and high Mach number test facilities that have been instrumental in the development of the J58 engine for the USAF YF-12A and SR-71 aircraft. The JTF17 development team will be headed by the same program manager as was responsible for the successful J58 development. The same facilities, enlarged in airflow, will be employed.

Production engine deliveries to be made in Phase V will be made from our Connecticut Operations facility in East Hartford, Connecticut, under the same system of management that has proved effective in producing both RL10 rocket engines and J58 turbojet engines in Connecticut with the over-all program management and engineering control residing in Florida.

Adequate manpower and facilities for both development and production programs will be available for the SST program. In addition to the existing facilities, United Aircraft Corporation has committed itself, if selected for the Phase III SST Engine Development Program, to expend approximately \$30,000,000 in corporate funds for additional capital improvements required for the JTF17 Phase III program. Furthermore, when the supersonic transport starts passenger carrying operation, the airlines using the engines can be supported by the largest worldwide field engineering and service organization devoted exclusively to aircraft engines. One hundred and two of the world's airlines now are operating, or have on order, turbojet or turbofan engines designed and developed by Pratt & Whitney Aircraft. These airlines receive support from a product support organization having representatives in more than 200 locations in 22 countries throughout the world.

Our proposal reflects the six years of intensive SST study and research efforts which have been performed at our Connecticut facilities and at our Florida Research and Development Center and benefits from the demonstrator engine testing which has been conducted during the Phase II-C program. It also benefits from the experience obtained during the accumulation of more than 1,000,000 miles of supersonic cruise flight above Mach 2.7; every day, on the average, the J58 powered YF-12A and SR-71 aircraft accumulate more Mach 3.0 flight time than all other supersonic aircraft have accumulated at this flight speed during their entire existence. This experience will accumulate at an increasing rate during the SST Phase III

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September 2, 1966

and subsequent phases and can be directly and immediately applied to the SST engine development.

We believe that the JTF17 augmented turbofan engine combines the airline-proven turbofan subsonic performance advantages with the demonstrator-engine-proven highly efficient ram induction augmentor configuration to produce a design which offers the following advantages in a supersonic transport application:

- Lower Engine Noise Levels
- Better Payload - Range Characteristics
- Better Nonstandard Day Performance
- Better Augmentor Durability
- Lower Fuel Reserves
- Adequate Growth Potential

These advantages are discussed in detail in the various sections of the proposal and in the Summary, Volume I.

With regard to costs, we are particularly pleased that our Phase II-C experience in the actual building and testing of SST engines of essentially the same size as the proposed Phase III engine supports a significant reduction from our previously estimated costs for Phase III. Our estimate of the cost of performing Phase III, including development, manufacture of ground test and prototype engines, and product support, is \$290,087,000. Our estimate of the unit cost of production engines is \$1,210,627.

Engine/airframe compatibility agreements which have been negotiated with both airframe manufacturers will ensure close coordination of effort, elimination of duplication of effort, consideration of all important interface areas, and resolution of possible disagreements. These compatibility agreements recognize the responsibility of each of the parties to the Government, to ultimate customers, and to each other. They provide a sound basis for working together and a method of settling disagreements with minimal recourse to the Government, recognizing that team effort on this program is essential for success.

In this program, we recognize the Government must know at all times where the contractors stand, what problems are being met, and what progress is being made toward ultimate goals. Therefore, our proposal includes detailed technical and management plans that describe the work to be undertaken, and our approach to the problem. If awarded the Phase III contract, we shall continue to keep the Government advised by regular updating of these plans and programs, by comprehensive reports, and by personal

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Major General J. C. Maxwell

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September 2, 1966

contact with the Government's assigned project people.

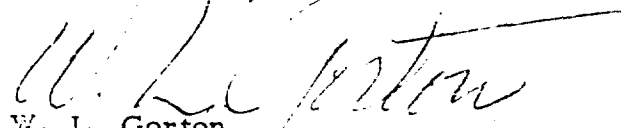
In summary, the engine program which we have proposed, backed up by our unique combination of high Mach number continuous cruise experience and our airline transport background, offers the minimum risk in attaining the reliable, efficient powerplant so vital to the development of a safe and economical supersonic transport for the world's airlines because:

1. We are proposing an engine that has the same frame size and the same specific airflow as the engines demonstrated successfully in Phase II-C.
2. We are offering a cycle and a design which we believe will have the operational flexibility, reliability, and durability that the airlines need and expect.
3. The development organization and the facilities are the same as were used successfully in developing the only continuous cruise, Mach 2.7+ engine currently in daily operation - the J58.
4. We have a record of meeting program performance commitments relating to initial engine deliveries, engine weight, thrust, and thrust specific fuel consumption. The JT3C, the JT4A, the JT3D, and the JT8D engines now in airline service all attest to this record.

Pratt & Whitney Aircraft is ready to proceed with confidence if awarded the Federal Aviation Agency's Phase III SST Engine Development Program.

Sincerely,

UNITED AIRCRAFT CORPORATION  
Pratt & Whitney Aircraft Division



W. L. Gorton  
General Manager  
Florida Research and Development Center



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SEPTEMBER 1966  
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**ENGINE PROPOSAL  
FOR PHASE III OF THE  
SUPERSONIC TRANSPORT DEVELOPMENT PROGRAM**

**VOLUME I.  
SUMMARY** (u) 8  
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**Pratt & Whitney Aircraft**

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Volume I

**SECTION I  
INTRODUCTION**

Pratt & Whitney Aircraft proposes for Phase III of the United States Supersonic Transport program to develop the JTF17 augmented turbofan engine, to deliver prototypes, and to support the engine through 100 hours of prototype aircraft flight testing. In making this proposal, the company has kept a larger objective in view: to provide a reliable engine with long life that will prove economical in commercial airline service. Meeting this long-term objective requires understanding the new problems peculiar to high supersonic cruise operation, while continuing to recognize the problems faced in daily operation by the world's airlines. Solutions to these problems are provided by the JTF17 design and by Pratt & Whitney Aircraft's existing world-wide support organization that serves the needs of the free world's airlines.

The 61,000-lb takeoff thrust JTF17A-21 engine is essentially the same design as the engines being tested today (figure 1). During the Phase II-C testing of this engine, the concept has been proved practical in over 86 hours of trouble-free operation, the engine has been operated successfully at SST cruise conditions, the turbine cooling approach has been confirmed by operation at full-rated turbine temperature, and the engine weight estimate has been validated. The blow-in-door exhaust system proposed for the JTF17 is patterned after the one used successfully in the YF-12A and SR-71 aircraft.

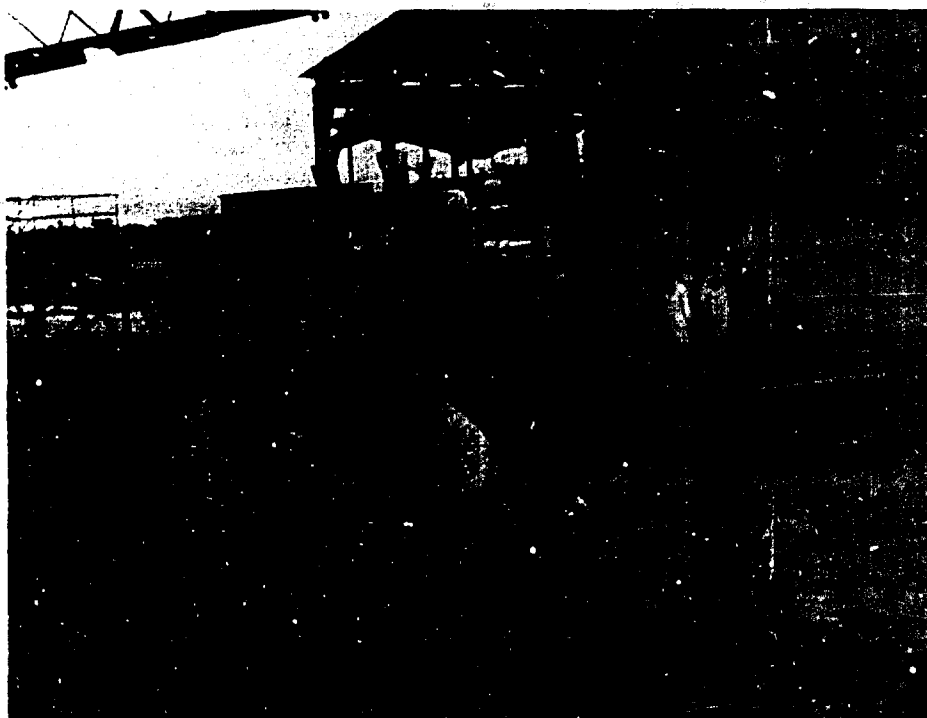


Figure 1. Pratt & Whitney Aircraft JTF17  
Engines At Test

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The materials selected for the JTF17 to obtain adequate strength and life at high temperature are mainly the same materials used in the J58, so that producibility has been established, properties have been fully documented, production processes have been de-bugged, and the quality-control procedures peculiar to these alloys have been developed. The application of J58 technology to the JTF17 design, the fact that the specific airflow and engine frame size are the same for the Phase II-C engine as for the proposed Phase III engine, and the successful demonstrator engine running at Mach 2.7 cruise conditions afford a low-risk approach to meeting the objectives for the supersonic transport.

Recognizing the airlines' need for long life, Pratt & Whitney Aircraft has included in the JTF17 design a duct heater cooled by fan discharge air to provide metal temperatures in the augmentor no higher than those in existing commercial engine combustion systems. A comparison of this cooled augmentation system and an afterburner on a high-turbine-temperature engine is seen in figures 2 and 3. In addition to this basic improvement in engine life, the duct heating turbofan cycle offers improved hot-day aircraft performance, a vital consideration on many airline routes. The subsonic fuel consumption advantage of the basic turbofan is also retained, with resulting improvement in operating flexibility.

In July 1965, Pratt & Whitney Aircraft transferred the responsibility for the SST propulsion program to the Florida Research and Development Center (figure 4) to take advantage of the specialized engineering background and high Mach number test facilities there that had been instrumental in the development of the supersonic J58 engine. The program management concept for continuing work under Phase III of the Supersonic Transport Program will be the same as that used on other major projects at the Florida Research and Development Center. Mr. William H. Brown, currently J58 program manager, and Mr. Gordon A. Titcomb, currently the Phase II-C SST program manager, as JTF17 Program Manager and Deputy Program Manager, respectively, will be responsible for all aspects of the SST propulsion program, reporting directly to the General Manager of the Florida Research and Development Center, Mr. W. L. Gorton. The current JTF17 team will be augmented by additional Florida Research and Development Center personnel experienced in high Mach number engine development, in prototype engine manufacture, and in product support. The initial engine development, prototype engine deliveries, and flight test support including engine overhauls will be accomplished at the Florida Research and Development Center, as will the engine certification program and the continuing development needed to support the engine in airline service. This work will be directed by a Development Manager, a Delivery Manager, and a Product Support Manager, all reporting to the JTF17 Program Manager. Positive action will be taken by establishing a Design Review Board of cognizant senior engineers to incorporate in the JTF17 engine any relevant improvements found necessary in the continuing Mach 3+ operation of the J58 or in the commercial service of current subsonic engines.

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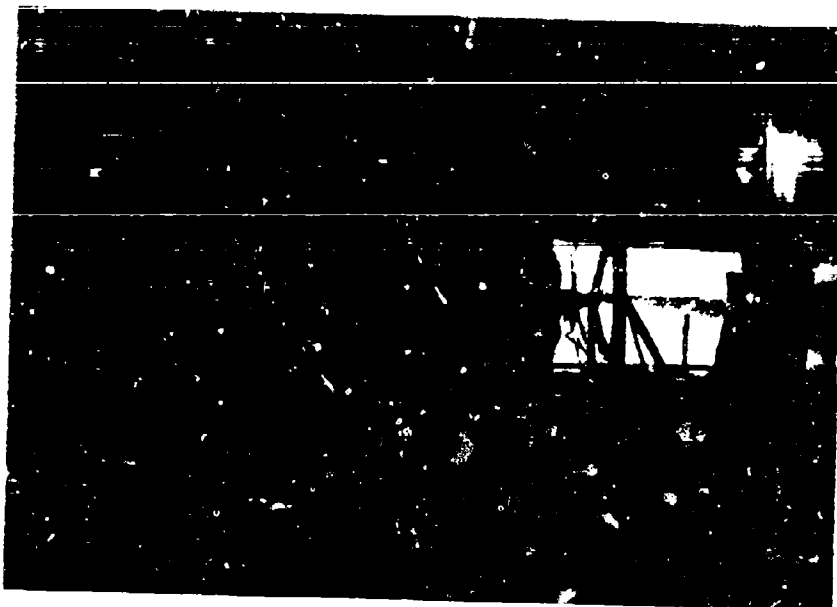


Figure 2. JTF17 Engine Operation With Duct Heating

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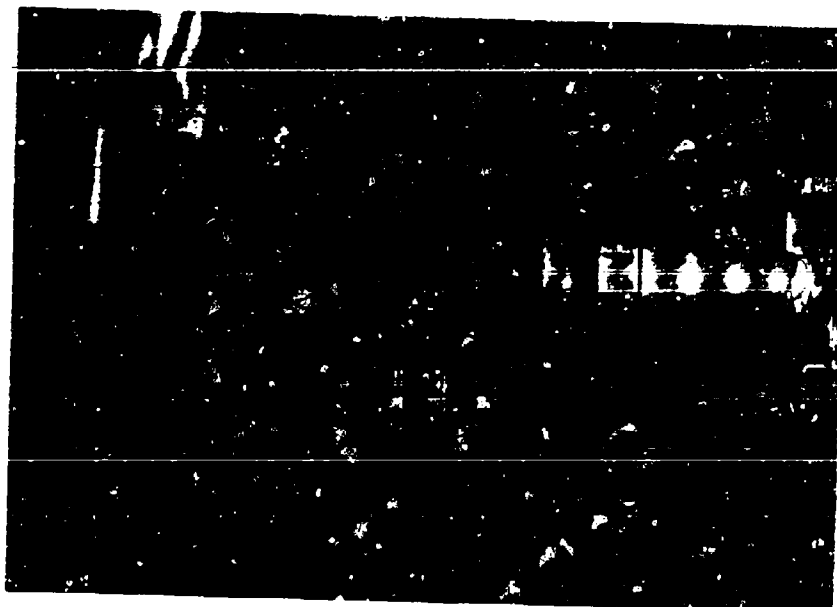


Figure 3. Afterburner on a High Turbine Temperature Engine

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The production engine deliveries in Phase V will be made from Connecticut Operations (figure 5), using the same system of management that proved effective in producing both RL10 rocket engines and J58 turbojet engines in Connecticut with the overall program management and engineering control residing in Florida. For this phase of the JTF17 program, a production manager in Connecticut will be named for the delivery program. Engine development and configuration management will remain a responsibility of the Florida-based program management. Throughout the program, Pratt & Whitney Aircraft's existing world-wide product support organization of airlines operations engineers, service engineers, spares personnel, and field engineers will contribute the same skills that they have in previous commercial turbine engine programs such as the JT3, JT4, JT3D, and JT8D. Product support representatives experienced in dealing with airline problems are currently stationed in 22 countries. Both directly, and through these product support groups, the airlines will be invited to continue reviewing the JTF17 design and development progress so that their specific requirements can be anticipated.

The component and engine development program planned for the JTF17 reflects the special development techniques found necessary in qualifying the J58 for production. For example, one-half of the engine testing to be conducted by the time the JTF17 is certificated will be at simulated high Mach number conditions. United Aircraft Corporation will provide its SST development team with additional high Mach number engine test stands so that this testing can be conducted on-site, and around the clock without interference from other programs. The overall JTF17 development program of 14,500 hours of engine testing prior to engine certification amounts to nearly 50% more engine testing, and a year longer program, than was the case with the J58 program at the time that the engine passed its 150-hour test. This added effort is designed to provide the longer engine life required for commercial use as compared to military use. The JTF17 program schedule (shown below), which meets both Lockheed and Boeing requirements, is well within the capability demonstrated in the J58 program:

**JTF17 Mileposts**

Flight Test Status	June 1969
Deliver First Flight Prototype	July 1969
Engine Certification	December 1971
Deliver First Production Engine	January 1972

Additional factors further assure meeting this schedule: first, a declining work load at the Florida Research and Development Center provides capacity for the engineering development, prototype delivery, and flight test phase; second, new materials and processes of manufacture such as required development for the J58 are not indicated; third, an experienced development team that has previously worked together and has a unique background of both high Mach number and commercial turbine engine experience is ready now; and fourth, open production capacity will exist in Connecticut by the time Phase V is initiated.

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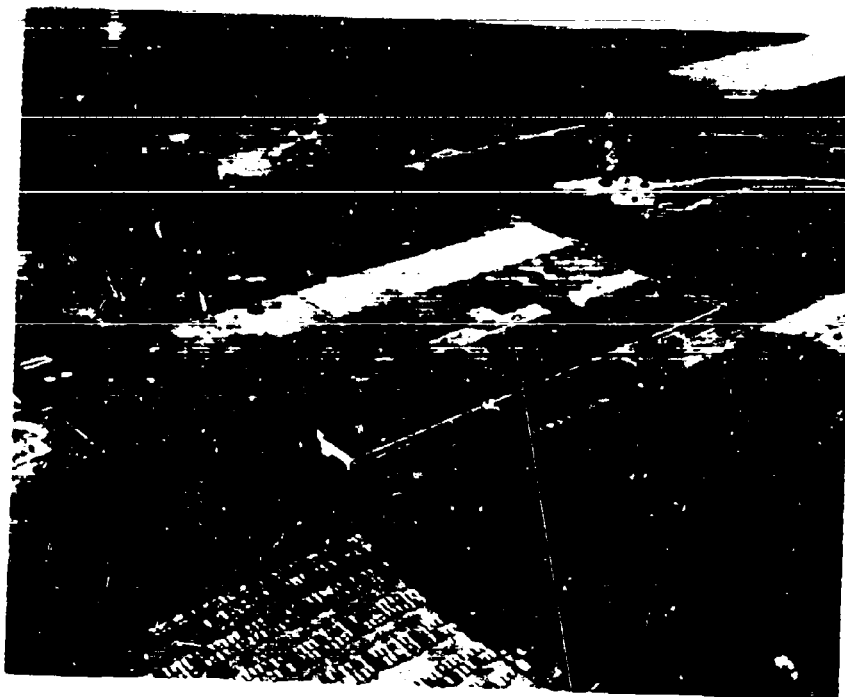


Figure 4. Florida Research and Development  
Center Manufacturing and Office  
Building

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Figure 5. East Hartford Plant

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The estimated cost of the JTF17 development program proposed to meet the SST objectives for engine life and reliability is \$325 million from the end of Phase II-C through engine certification in December 1971; a continued development program is planned after certification to improve the engine in service. The estimated costs for the various phases of the SST program are summarized below:

Assumed Time Frame	Program Phase	Estimated Cost
July 1965 through December 1966	Phase II-C (demonstrator)	\$ 50 Million
January 1966 through September 15, 1970	Phase III (FTS development, 20 prototype engines, and support for 100 hours of aircraft flying)	290 Million
September 15, 1969 through December 1971	Phase IV (Engine certifi- cation, plus continued development and flight test support through air- craft certification)	252 Million
January 1972 through May 1979	Phase V (Continued engine development)	180 Million

The estimated unit engine cost established in accordance with the FAA's instructions is \$1.21 million, for the engines to be delivered during Phase V.

The Mach 3+ flight time obtained with J58-powered aircraft each day now exceeds the total Mach 3.0 flight time obtained by all other aircraft to date. As this supersonic experience continues to accumulate in the years before the flight of the first supersonic transport, the Florida Research and Development Center engineering team will continue to apply to the JTF17 the hard lessons learned from the J58 program. In commercial service, other Pratt & Whitney Aircraft engines have demonstrated a maintenance cost per lb thrust per hour one-half that of competitive engines, and unmatched rate of TBO growth, and the lowest premature-removal rate in the industry. The same development philosophy that made this record possible will be applied to the SST propulsion task. This extensive and continuing high Mach number experience, combined with extensive and continuing commercial turbine engine experience, provides a singular understanding of the SST propulsion problems; an understanding which in the final analysis will result in the most economical engine.

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**PWA PP 66-100**

**Volume I**

**SECTION II  
PROGRAM MANAGEMENT**

**A. GENERAL**

Pratt & Whitney Aircraft's management philosophy for the SST Program will be responsive to the vital interests of (1) the airlines, who must find that the United States supersonic transport is a safe, reliable, and economically attractive addition to their fleets; (2) of the airframe contractor, who must assume systems responsibility for the major goals of the program; and (3) of the Federal Aviation Agency, which by reason of commitment of large Government appropriations, must be concerned with program decisions involving contract cost, certain critical performance criteria, and key program milestones.

In recognition of the airlines' role, Pratt & Whitney Aircraft will encourage the airlines to state their desires throughout the SST design, development, and production phases so that configuration decisions in particular will be influenced by the airlines to the maximum practical degree. In addition to the traditional P&WA/airline contacts, the airlines will be asked to participate formally in program reviews for the purpose of influencing the design, reliability, safety, maintainability, and performance aspects of the program. It is contemplated that airline cooperation will make the airline industry committees an important and effective voice for the SST program. Accordingly, the contribution of these committees will be actively sought.

In recognition of the airframe contractor's role of total system responsibility, P&WA has negotiated an SST Airframe/Engine Compatibility Agreement, which sets forth coordinated engine/airframe interface plans, with each competing airframe contractor. In implementing the agreements, the JTF17 Program Management will ensure that no element of necessary work is overlooked and that minimum duplication of effort exists between the airframe contractor and P&WA.

In recognition of the FAA's role in the management of the program for the Government, P&WA will provide comprehensive plans for the Phase III Program. These plans are described in Volumes III, IV, and V, of this proposal, and include a detailed work plan, a test and certification plan, and management plans. P&WA will submit changes affecting critical performance criteria or contract cost and schedules to the FAA for approval.

**B. ORGANIZATION**

In July 1965, Pratt & Whitney Aircraft transferred the responsibility for its part in the SST propulsion program to the Florida Research and Development Center (FRDC). This move was designed to make available to the SST program the specialized engineering background and high-Mach-number facilities that had been instrumental in the development of the J58 engine. With the decline in other programs at FRDC, a team experienced in design, development, prototype delivery, product support, and overall program management is also available for the JTF17. The work described in this proposal for Phase III of the SST program will be directed and conducted at Pratt & Whitney Aircraft's Florida Research and Development Center.

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The Florida Research and Development Center is a separate profit center of the Pratt & Whitney Aircraft Division, and has both the authority and the responsibility for managing the programs conducted in Florida, within the bounds of overall corporate and division policy. The Center may propose new programs and enter into contracts. Approval by the Division President is obtained when commitments are made by the Center that involve corporate funds or use of other company facilities.

The Florida Research and Development Center has recognized that special problems are created by its physical separation from P&WA Connecticut Operations. For this reason, the project engineering system traditional at Pratt & Whitney Aircraft has been expanded in the course of the RL10 and J58 programs to place all aspects of these programs under the full-time direction of a single individual or Program Manager. This program manager directs the activities for his program (including development, delivery, and product support) whether the work is performed in Connecticut, Florida, or in the field. In addition, special interplant communications systems and scheduled interplant visits have been brought into play to provide effective coordination between Florida and Connecticut.

In practice, the program manager's authority over the operating department activities transcends the functional organization's lines. A program manager is selected based on his qualifications to organize, direct, and control the technical and business management of his program. The fundamental criterion governing the placement of the program in the organization is to provide active management participation at a level commensurate with the needs of the program. For example, the RL10 and J58 managers reported to the General Manager of the Florida Research and Development Center during the critical phases of these programs; currently these program managers report to the Chief Engineer. Other programs that involve primarily research and development currently report to the Director of Applied Research or to the Assistant Chief Engineer - Advanced Technology. Fundamentally, the program manager is successful in directing his work through the overlay of program management on the line departments because all elements of the organization are indoctrinated in this method of operation by experience and as a matter of policy, and because the program manager authorizes and controls the incurring of costs. The success of this program management system at the Florida Research and Development Center is borne out by the results achieved in two major programs encompassing development and production phases. The JT11 turbojet and the RL10 liquid oxygen/hydrogen rocket engines were both developed at the Florida Research and Development Center and later produced at Pratt & Whitney Aircraft's Connecticut Operations. Program management for both these programs has remained with the Florida Research and Development Center throughout the development, production, and product support phases. The JT11 turbojet engines now in production are the only turbojet engines known to be flying daily at sustained speeds in excess of 2000 miles per hour. Liquid hydrogen was little more than a laboratory curiosity when the company began the development of the RL10 hydrogen-fueled rocket engine in 1956; from this challenging beginning, the RL10 space engine has achieved a record of complete success in all of its missions, the latest being the Surveyor soft lunar landing.

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The program management concept which will be used for Phase III is the same one that has been used at the Florida Research and Development Center since 1961 for the J58, the RL10, and other research and development programs. The personnel who will manage the various aspects of the JTF17 program and those who will conduct the work not only have broad experience in powerplant development and production, but also have the benefit of having all worked together as a team on other programs. In many cases, these associations have existed for ten or twenty years.

For Phase III of the SST Program, the JTF17 Program Manager will report directly to the General Manager of the Florida Research and Development Center. The general relation of the JTF17 program to the Florida Research and Development Center staff functions, to the six operating departments, and to other programs is shown on figure 6. Each functional, or operating department is, of course, specialty oriented and as such is charged with the responsibility of acquiring and maintaining the necessary high level of competence in the specialized fields required for the fulfillment of business obligations. This basic functional organization provides the type and level of effort that may be required by each program within the constraints of time, costs, and performance as established by the Program Manager.

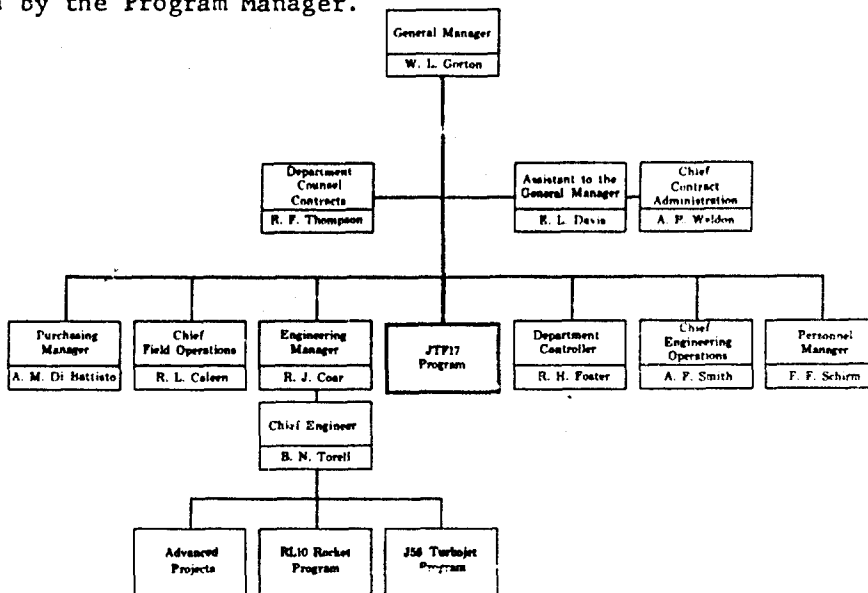


Figure 6. Pratt & Whitney Aircraft Florida Research and Development Center Functional Organization

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### C. PROGRAM RESPONSIBILITIES

For Phase III of the SST Program, Mr. W. H. Brown, currently the J58 Program Manager, has been selected to be JTF17 Program Manager, and Mr. G. A. Titcomb, currently the Phase II-C JTF17 Program Manager, has been selected to be JTF17 Deputy Program Manager.

Mr. Brown has been selected as Program Manager to take full advantage of the experience he gained in managing the J58 engine program. In that program, he has pioneered in solving the development problems associated with qualifying a turbine engine to operate continuously at high turbine temperatures in an environment more hostile than foreseen for the SST.

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He has also demonstrated the ability in the YF-12A and SR-71 airplane programs to resolve interface compatibility problems between the engine and its installation, and he has provided effective field support in the post-certification phase. He was Project Engineer on the JT3 engine when it was first flown in the prototype Boeing 707 (367-80), and later on the JT4 engine, and was directly responsible for the development program necessary to obtain the commercial Type Certificates for these two engines.

Mr. Titcomb's experience in program management includes his current position as Program Manager of the JTF17 Phase II-C activity, and his prior assignment as RL10 Program Manager where he was responsible for development, delivery, and field support of the world's first hydrogen-fueled rocket engine. He has 18 years experience at Pratt & Whitney Aircraft including development responsibility as project engineer in the J52, JT4, and JT3D engine programs.

Both Mr. Brown and Mr. Titcomb have had overall program management responsibility for previous programs where the development was conducted in Florida, and which involved product support from the Connecticut functional departments and the production delivery of engines manufactured in Connecticut.

The day-to-day direction of the JTF17 program will be provided by the Program Manager and his deputy, assisted by five managers assigned to the following areas of responsibility:

Development	Product Support
Program Controls	Engine Delivery.
Product Assurance	

A JTF17 Management Committee having as members the General Manager, the heads of the Florida Research and Development Center line departments, and the Assistant Sales Manager will meet periodically to establish policy and provide management guidance for the program. The JTF17 program management will also be responsive to the airlines' requirements as expressed by an Airline Review Board. This overall JTF17 program management organization is summarized in figure 7. The specific functions of the five Managers assigned to the program and their relation to the functional departments are described in Report I, Volume V of this proposal. The overall assignment of responsibilities according to the Phase III work breakdown structure is shown in figure 8.

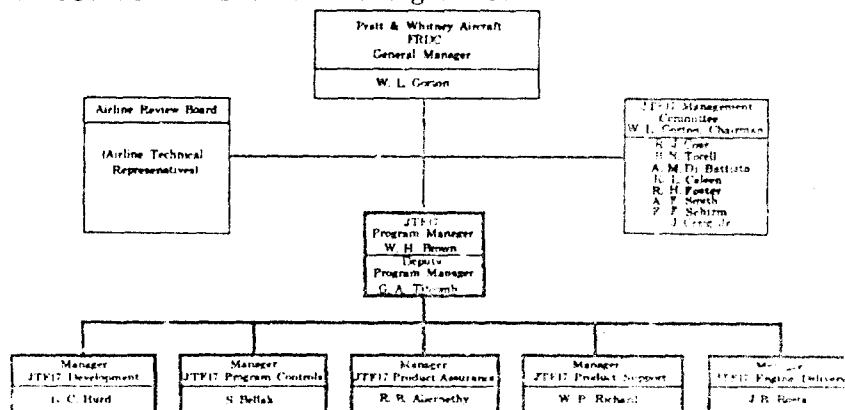


Figure 7. JTF17 Program Management

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Engine & Component Development	Program Manager and Deputy Program Manager	Project Engineers	Product Control Group	Data Management Group	Program Planning Group	Chief - Reliability	Chief - Maintainability	Chief - Human Engineering and Human Engineering	Safety Engineer	Value Engineer	Chief - Configuration Management	Standardization Engineer	Quality Assurance	Product Support Manager	Delivery Manager	Design	Performance Analysis and Statistics	Materials Laboratory	Test Operations	Manufacturing Operations	Purchasing	Flight Operations	Engineers	Support Services	Space	Verification	Field Engineers	Department Controller
Engine Design	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Fabrication and Assembly	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Tooling	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Engine Instrumentation	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Test Equipment	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Engine Test (Ground)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Engine Performance	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Inlet System Compatibility	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Boiler	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Growth Potential	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Fan and Compressor	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Bearings, Seals, Gears, Lubricants	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Fuel	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Manufacturing and Materials	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Weight Control	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Management Controls and Product Assurance	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Coordination	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Maintainability and Human Engineering	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Reliability	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Quality Assurance	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Value Engineering	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Configuration Management	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Safety	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Test Planning and Integration	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Data Management	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Program Management	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Facilities	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Cost Analysis	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Proposals	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Delivery and Product Support	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Ground, Test, and Flight Engines	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Tooling	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Performance	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Mockup	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Spares	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Overhaul	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Flight Test Evaluation	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Data and Handbooks	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Training	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Ground Support Equipment	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	

Figure 8. Work Breakdown Structure vs Functional Responsibility

- Code:
1. Prime responsibility
  2. Shared responsibility
  3. Active participation
  4. Advisory function
  5. Monitoring function
  6. Not applicable

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**SECTION III**  
**DESIGN AND DEVELOPMENT**

**A. PHASE II-C ACHIEVEMENTS**

**1. Cycle Selection**

During Phase II, Pratt & Whitney Aircraft with the concurrence of both airframe manufacturers selected the duct heating turbofan engine based on extensive cycle and mission analyses that showed the superiority of the turbofan engine in the areas of range/payload performance, safety, noise, inlet/engine compatibility and growth potential. For the super-sonic transport basic mission at equal payloads, Pratt & Whitney Aircraft's studies have shown that the turbofan gives 170 statute miles greater range potential; or trading range for payload, 6300 pounds greater payload than the turbojet in the fixed wing aircraft. Similar advantages were shown in the swing-wing aircraft analysis.

**2. Engine Design**

The JTF17A-21 engine, a two-spool, duct-heating turbofan (figures 9 and 10) was designed during Phase II to meet the following objectives:

**1. High Performance**

- |                  |               |
|------------------|---------------|
| a. SLTO Thrust   | 61,000 pounds |
| b. SLTO SFC      | 1.77          |
| c. Cruise Thrust | 16,000 pounds |
| d. Cruise SFC    | 1.58          |

(At Mach 2.7 and 65,000 feet altitude)

**2. Efficient use of structure and materials**

- a. Basic Engine Weight 9860 pounds (for L 2000 installation)  
9910 pounds (for B 2707 installation)

**3. Reliability, structural integrity, and safety**

**4. Engine Life**

- a. Major cases - 50,000 hours  
b. Disks - 20,000 hours  
c. Easily replaceable parts - 10,000 hours  
d. Hot section inspection - 5000 hours

**5. Superior growth potential**

**6. Acceptable noise levels (less than 116 PNdb at takeoff)**

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7. Versatility to match aircraft requirements
8. Advanced concepts to facilitate airline maintenance
9. Minimum development risks

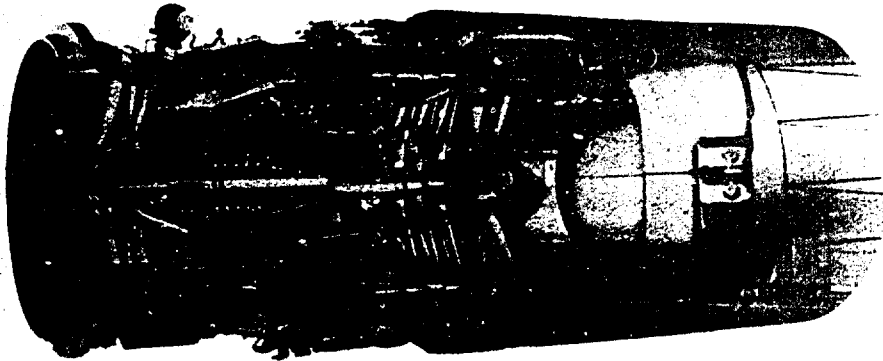


Figure 9. JTF17A-21 Engine Cutaway

UGS 2696A

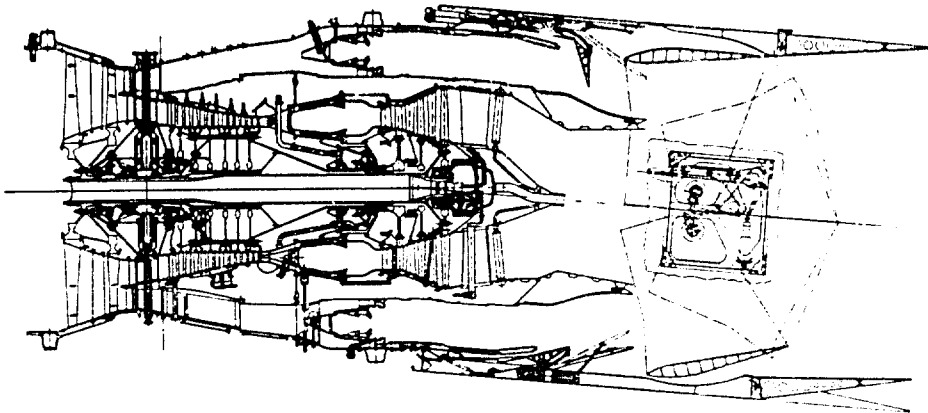


Figure 10. JTF17A-21 Cross Section

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The engine design was optimized to achieve maximum range/payload for a given gross takeoff weight with acceptable noise levels. Maximum turbine inlet and augmentor discharge temperatures were selected consistent with advanced design concepts to provide maximum efficiency and airflow. Pressure ratios and percent augmentation were established considering optimum mission performance and minimum weight. Selection of a basic 650 lb/sec airflow size for the Phase II-C demonstrator engine was coordinated with the two airframe manufacturers. The 687 lb/sec airflow JTF17A-21 engine proposed for Phase III is substantially this same Phase II-C engine with a slight increase in fan blade length within the original engine envelope. The performance of the engine system proposed has been completely defined in the Engine Model Specifications. Digital computer cycle matching decks have been prepared as part of each model specification and furnished to the airframe contractors, FAA, and appropriate government agencies. Dynamic simulations of important steady-state and transient engine conditions have been simulated and the results have been used to improve the engine design.

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The JTF17 engine design has the growth potential to provide increased thrust for takeoff and transonic acceleration, lower cruise TSFC, and extension of the operational envelope to Mach 3 or higher. Historically, airplane gross weights have increased with time and there is no reason to doubt that the SST will be different. Figures 11 and 12 show the expected growth for the JTF17 in increased thrust and decreased cruise TSFC. Thrust can be increased within the current frame size by increasing the fan specific flow and raising the turbine inlet temperature. Improvements in exhaust nozzle performance could be incorporated on existing engines or applied to uprated engines. Because a 0.1% change in nozzle efficiency adds approximately 500 pounds of payload for a range-limited flight, this area warrants considerable development effort to make even small gains. The potential gain in range with increase of Mach number is shown in figure 13. Because the duct heater operates more like a ramjet at higher flight Mach numbers, the cycle efficiency improves faster than the turbojet. The extensive background of the J58 development effort and the continuing accumulation of Mach 3+ flight experience will provide the necessary technology to provide this capability for the JTF17.

Improved maintainability has been a prime consideration in the basic design of the engine. The major subsections of the engine may be removed with minimum disassembly. The entire 2-stage fan-stator package can be removed from the front without disturbing the No. 1 thrust bearing or the front mount case. Additionally, the 1st-stage fan disk and blade assembly can be separately removed from the engine from the front, and provisions have been made to replace individual fan blades in the field without rebalance. Similarly, the low and high rotor main thrust bearings can be removed, inspected, and replaced from the front. The reverser-suppressor may be unbolted and removed as a unit, as can the duct heater.

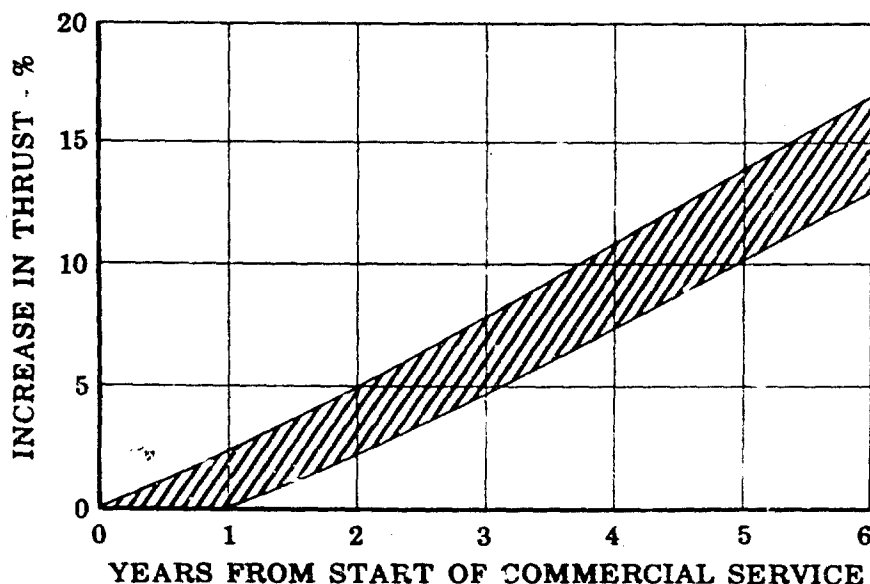


Figure 11. JTF17 Growth-Takeoff, Transonic Thrust

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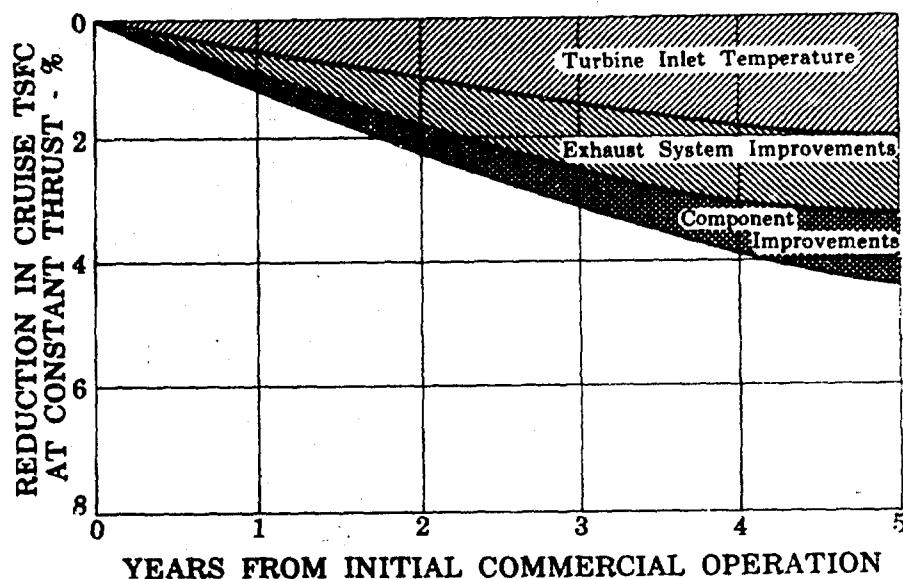


Figure 12. JTF17 Growth-Cruise TSFC Reduction FD 17079

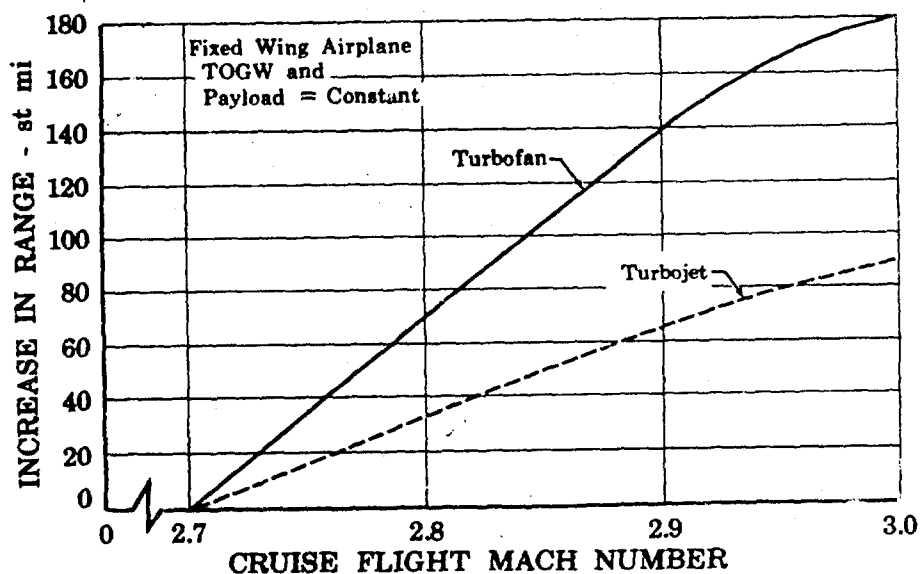


Figure 13. Cruise Mach No. Effect on Design Range FD 17082

Progressively the turbine exhaust case, low turbine rotor and case assembly, and high turbine disk and blade assembly can be removed from the rear. The ability to remove, refurbish, and replace major units without sending the engine to overhaul will be a major economic advantage to the airlines. Additional maintainability features include borescope provisions for each stage of the high compressor, accessible while the engine is installed in the airplane, and borescope holes to inspect the primary combustor and the turbine blades. Generous use of visual access to the inside of the engine to assess the parts is in direct response to airline desires. Other maintainability features are chip detectors, scavenge pump screens, and

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vibration pickups to pinpoint problem areas prior to escalation to expensive overhaul. There are also provisions for radioisotope inspection through the bore of the low shaft from either the front or the rear of the engine. The JTF17 has been designed to take advantage of Airframe Integrated Data Systems (AIDS) in the form that each airline finds most adaptable to its mode of operation. Airline maintainability also means repairability. The unique background of experience gained by PWA on the J58 has evolved repair procedures for materials not now in common use by the airlines, but necessary for long life of a Mach 2.7 cruise engine. These include case weld repairs for A-110 Titanium, Inco 718, and Waspaloy.

### **3. Engine Testing**

Two JTF17 engines were built and have now been tested for more than 86 hours over a wide range of simulated operating conditions, including the 2.7 Mach number 65,000 feet cruise point. Sea level operation has been extended to 99% rated rotor speed and more than 26 hours have been run at turbine inlet temperatures of 2000°F to 2350°F.

Steady progress has been made in increasing the thrust range of the engine by the incorporation of compressor improvements developed through the compressor rig program. Successful operation of the annular primary and duct heater combustors has permitted trouble free running up to design maximum fuel air ratios. To date, an augmented thrust level of 47,600 pounds, a value within 10% of that predicted for the demonstrator engine, has been achieved.

Successful duct heater lights have been made on every attempt at F/A ratios as low as 0.0016 with no attendant problems relative to fan or duct heater instability. The 19 hours of duct heating test experience to date tends to verify the anticipated durability advantage of the duct heater over the afterburner of a typical turbojet. Because of the unique ability of the ram-induction burner to ignite at low fuel/air ratios, transient airflow changes were less than 2% at the engine inlet when lighting the duct heater at M 2.7, 65,000 ft conditions.

The first JTF17 engine was run nine months after beginning Phase II-C. Operation both on the sea level test stand and at Mach 2.7 cruise conditions has been notably trouble-free. The only significant mechanical problem to date was an airfoil failure in the high compressor during the first Mach 2.7 run, a problem that has been corrected by incorporation of a mid-span-shrouded blade.

Installation of the engine in the Florida Research and Development Center altitude environmental facility is shown in figure 14. Despite conservative matching to accommodate the high pressure compressor surge deficiency at sea level takeoff, preliminary data indicates that the engine specific fuel consumption at this simulated cruise condition was within 5% of the prototype engine goal. By the end of August 1966, the JTF17 had been operated more than 17 hours above M = 2.0 conditions.

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Figure 14. JTF17 Engine Installed in FRDC  
Altitude Environmental Facility

FE 61153

#### 4. Component Testing

The extensive component rig test program has made many contributions to the success of the demonstrator program. Advanced test techniques, many developed during the J58 engine program and specifically tailored to the unique requirements of a high Mach number engine, allowed the rapid accumulation of required aerodynamic, heat transfer, and structural data. For example, the use of automatic data systems on the high pressure compressor rig testing has allowed the complete evaluation of 5 aerodynamic configurations in 80 hours of testing.

##### a. Fan and Compressor

The two-stage overhung fan is driven by a two-stage turbine and produces a sea level takeoff (SLTO) pressure ratio of 2.9. The use of an overhung fan eliminates the conventional inlet guide vane structure and the inherent anticing problems associated with inlet guide vanes. It also provides a more durable compressor section by increasing resistance to damage by foreign object ingestion. The six-stage compressor is driven by a single-stage turbine and with the fan produces an overall engine pressure ratio of 12.95. The variable inlet guide vane for the high pressure compressor permits optimum compressor performance over the required operating range and also serves as a windmill brake when required.

Fifteen aerodynamic modifications have been tested in the fan compressor test rig with no blade failures encountered in more than 435 hours of operation. Fan flow capacity confirmed the increase of total airflow to 687 lb/sec for the JTF17A-21 rating.

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Improvements in the fan engine side surge line are required to provide the desired operating margins, and an increase in efficiency of 2 to 3 percent at SLTO is needed to reach the desired prototype performance levels. Such improvements appear readily achievable through application of the root aerodynamics of the JTF14 fan. This fan configuration has demonstrated the surge margin and the added fan efficiency needed for the JTF17 fan. Fan duct side efficiency has been developed to within 1% of the prototype engine goals at all significant flight conditions.

Five aerodynamic configurations have been tested in the high pressure compressor rig program. Efficiency and surge lines have been progressively improved, and cruise efficiency now exceeds prototype goals at the required surge margin. Although improvement in surge margin is needed at SLTO, the prototype efficiency goal has been achieved. The lack of stall margin at the SLTO condition has been isolated to premature root stall; single-stage rotating cascade tests of corrective recambering indicate that this can be corrected.

b. Primary and Duct Heater Combustors

The annular ram-induction primary combustor and duct heater have demonstrated the ability to attain high heat release rates with high efficiency, uniform temperature profile, low pressure drop, and smooth ignition characteristics. A J58 type, balanced-flap nozzle is used to control fan back pressure and duct airflow for inlet matching.

The SST engine design requires adequate durability in the augmentation system. Experience with afterburners has generally been limited to short time operation in military service. By commercial airline standards, afterburner flameholders, fuel injection systems, and liners are short-lived because of the fundamental fact that they cannot be adequately cooled by hot turbine exhaust gas. The durability problems inherent in continuous-use afterburners have led Pratt & Whitney Aircraft to select the proposed duct-heater configuration.

The concept of duct augmentation makes it possible to use relatively cool fan air for augmentor combustion. Use of low temperature air facilitates cooling of the combustor parts, thus increasing combustor life, and the cool air forms a blanket to isolate hot combustor surfaces from the outer case structure. The airframe nacelle and structure adjacent to the engine also receive the benefits of lower engine outer case temperature. The highly successful engine operation of the primary and duct heater combustors is attributable to an extensive prior rig program. Advanced research on a new concept called "ram-induction," which is the basis of both combustor designs, was initiated at the Florida Research and Development Center in 1963. The concept avoids much of the diffusion and subsequent expansion loss common to conventional annular burners associated with the introduction of secondary and tertiary air into the combustion region. In the ram-induction combustor, this air is directed by efficient turning vanes into the combustion region with relatively little prior diffusion. Benefits of the principle are reduced diffuser length and weight, coupled with very high efficiency.

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Primary combustor rig testing has been accomplished in combustor segment rigs and on full-scale combustors installed in a modified JT4 engine. The accumulation of 351 hours of rig testing has provided a configuration with temperature distribution at the combustor discharge comparable with that of the exceptionally durable JT4 commercial engine. Prototype and production combustion efficiency and combustor pressure loss and sea level ignition goals have been demonstrated in full-scale and segment rig tests. Consideration given to smoke generation during the design phase of the combustor has been most beneficial. Engine smoke density measurements show that a reduction of approximately 50% below the JT3D and JT8D commercial turbofan densities has been achieved.

More than 497 hours of duct heater combustor testing have been accomplished in segment rigs and in a full-scale rig with comparably successful results. Prototype engine combustion efficiency and cold and burning pressure loss goals have been demonstrated. Successful ignition has been achieved at fuel/air ratios as low as 0.0016. This "soft" lighting characteristic produces a very small pressure change and has had no effect on fan stability in the 31 successful duct heater lights accomplished during engine testing.

c. Turbine

A single-stage high pressure turbine drives the six-stage compressor. Advanced aerodynamic design with airfoil and disk cooling techniques derived from successful J58 design has been incorporated to achieve the efficiency and long life required. A two-stage, controlled-vortex, low pressure turbine drives the two-stage fan. The controlled-vortex design permits higher efficiencies than the conventional free vortex design. Highly effective convective cooling techniques have been incorporated in all three stages of the turbine to optimize performance and enhance the life of the turbine vanes and blades. High-creep-strength material (IN-100) and an advanced coating (PWA 64) will give the turbine blades the long life required in the supersonic transport engine.

More than 655 hours of turbine blade testing in aerodynamic thermal shock and heat transfer rigs and in a JT4 test vehicle were accomplished in an evaluation of various types of blade materials, coatings, and cooling arrangements. Material tests confirmed the adequacy of the well-developed J58 turbine blade alloy, IN-100, for initial use and the potential of directionally solidified PWA 664 for turbine temperature or life growth. Oxidation erosion testing with salt and sulphur contaminants demonstrated the rapid deterioration of all uncooled current turbine alloys, particularly U-700, and the dramatic improvement which resulted with the application of several candidate Pratt & Whitney Aircraft coatings. A critical assessment of a number of turbine blade cooling methods showed the consistent superiority of a refinement of the J58 convectively cooled design with impingement cooling of the leading edge. When compared to film-cooled airfoils with surface discharge of cooling air, the convective design proved to be significantly superior in thermal fatigue tests, in aerodynamic losses, and in resistance to cooling flow interruption from contaminant or foreign object damage. In addition, the design was comparable in cooling effectiveness at the cooling airflows needed to maintain the desired blade metal temperatures of 1650°F.

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**d. Fuel and Oil**

The design of the JTF17 permits the use of currently available airline type oil: PWA 521 (Type II). This is accomplished by cooling the bearing compartments with fan discharge air to a temperature no higher than current commercial fan engines. Particular care has been taken in the design to minimize heat input into the oil by use of hydrostatic seals and insulation at key locations. These features will also avoid local hot spots which could otherwise cause oil breakdown and subsequent contamination of the oil system.

The engine is designed to operate with high TBO and long parts life using currently available airline fuels, PWA 522 (Jet A, A-1). The JTF17 fuel system is designed to make maximum use of the fuel as a heat sink before burning it in the duct heater or the primary combustor. At cruise conditions with fuel flows for expected cruise thrust requirements, the fuel may enter the fuel pump at temperatures of 235°F and still not exceed 300°F at the fuel nozzles, the temperature currently encountered during cruise on the JT3D. Only minor manifold deposits are encountered with the JT3D with an 8500 hour TBO.

**e. Exhaust System**

The reverser-suppressor, which includes the engine exhaust nozzle, performs three basic functions: (1) the controlled expansion of the exhaust gases at all flight conditions for optimum overall airplane performance, (2) redirection of exhaust gases for reverse thrust, and (3) suppression of engine exhaust noise. The reverser-suppressor (shown in figure III-2) consists of five major sections: (1) the main structure, which includes the support framework, the fixed outer skin, and engine attachment ring, (2) tertiary air doors between the forward structural members, (3) an integral shroud that, with the clamshells, forms the ejector throat, (4) clamshells that form the movable portion of the ejector throat and provide exhaust gas blockage for reverse thrust, and (5) the movable exit flaps, forming the variable diameter portion of the ejector nozzle.

In recognition of the very high sensitivity of the supersonic transport performance to the performance of the engine exhaust system, approximately 1600 hours of wind tunnel test time have been devoted toward its refinement. This testing has been greatly enhanced by the background of experience with the development of the J58 exhaust system. This engine also is used with a blow-in-door ejector, and like the SST is installed in an isolated nacelle. Subsonic performance of the ejector in this installation has met all objectives. Test methods developed on the J58 program that have provided excellent correlation of J58 model test data with YF12 flight test results have been applied to the JTF17 tests. Although the proposed SST powerplant installations differ greatly from the installation of the TF30 blow-in-door ejector in the F-111, close liaison is being maintained with efforts to isolate the cause of the subsonic drag problems on that airplane. This will ensure the application of all available knowledge to the SST installation.

Comparative tests of the JTF17 exhaust system have been conducted for the Lockheed configuration with both installed and uninstalled nacelle models. Uninstalled tests consisted of an isolated nacelle and installed

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tests employed a wing and nacelle model with aerodynamic simulation of the adjoining nacelle. It is most significant that installation losses were in accordance with predictions and that installed performance met the prototype engine goals. Prototype goals for reverse thrusts were also achieved in model tests of the reverser configuration. Reverse thrust is obtained by closing clamshells while holding the blow-in-doors open. A significant advantage of the fan engine is the low temperature of the mixed gases, approximately 700°F, exiting from the reverse doors. This eases the airframe impingement temperature problem and reduces reingestion of hot gases into the engine inlet.

**f. Controls and Accessory Drive Systems**

Accessory and external component drives are provided by three towershafts driven by the high rotor through a bevel gear system. One towershaft drives an accessory gearbox, located on top of the engine, that provides power takeoffs for aircraft accessories and for the engine starter. The left side towershaft drives the main engine gearbox, on which are mounted the gas generator fuel pump, the unitized fuel control, and the engine hydraulic pump.

The gas generator fuel pump is a two-stage unit incorporating a centrifugal boost stage, a full-flow micronic filter, and a gear-type high pressure stage. The unitized fuel control is a hydromechanical unit that schedules the fuel flow to the primary combustor and duct heater, controls the operation of the duct heater exhaust nozzle, and schedules operation of the high rotor inlet guide vanes, the compressor starter bleeds, and the thrust reverser system. The engine hydraulic pump is a piston pump that provides high pressure fuel to actuate the duct heater exhaust nozzle and thrust reverser system. Duct heater fuel is pumped by an engine-air-driven turbopump located on the right side of the engine. Engine fuel-oil coolers and an oil tank are also located on the right side of the engine. Dual low-voltage ignition systems are provided for both the primary combustor and the duct heater.

Dynamic simulation of the engine control mode and concept has been continued in Phase II-C. The object of this simulation program was to determine if engine control concepts that have proved dependable on current commercial engines and on the high Mach number J58 engine could be applied to control the JTF17. Results of this simulator program, including 1600 hours of computer analysis, showed the selected mode to be satisfactory for control of the JTF17 over its operating range and flight envelope. Dynamic simulations of the JTF17 engine control characteristics coupled with the Lockheed L-2000 and with the Boeing 2707 aircraft inlet characteristics are also being conducted to provide early evaluation of the compatibility of the selected control modes.

Operation of the initial experimental JTF17 engines is being accomplished using existing flight-type control system components to expedite the test program. The components used in this initial control system are basic J58 and TF30 units modified as necessary to provide the same functions and mode of control used in the JTF17 dynamic simulation program. J58 pumps of the same types that will be used on the final JTF17 engines are also being utilized. All of the fuel and control system components used for JTF17 testing are flight-type hardware and are engine mounted. The engine testing with these modified components has demonstrated the feasibility of the selected control modes.

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5. Engine Weight

The weights of the JTF17A-21 production engines are defined in the Engine Model Specifications as 9910 pounds and 9860 pounds for the Boeing and Lockheed models, respectively. Prototype engine weights are 12% higher. Pratt & Whitney Aircraft has developed a system of weight prediction and control that was applied to the JTF17 engine design during Phase II. Each component part was carefully estimated and controlled. The accuracy of this estimating system is confirmed by the fact that the actual weight of the first test engine proved to be 50 pounds less than the weight estimated for the engine. The extensive weight control program developed during Phase II will be continued through Phase III.

6. Noise Attenuation

Phase II-C tests and analyses indicate that the following FAA noise attenuation objectives can be met:

- |   |          |
|---|----------|
| 1. 1500 feet from centerline of runway        | 116 PNdb |
| 2. 3 statute miles from start of takeoff roll | 105 PNdb |
| 3. 1 statute mile from runway on approach     | 109 PNdb |

Current levels of unsuppressed and suppressed engine noise for Condition 1 are shown in figure 15. The potential for suppression devices to reduce the level of the predominant jet noise is also indicated.

Figure 16 shows noise levels for Condition 2 at the 3 mile point for the thrust levels the airframe manufacturers anticipate. The suppression devices, current and potential, include acoustic treatment of the duct heater diffuser to absorb fan generated noise, and reverser-suppressor noise at thrust cutback after takeoff may be obtained through the use of duct heating beyond the thrust cutback point. By means of this procedure, the required thrust level will be attained at a lower fan rotor speed. Engine noise reductions of 5 PNdb may be obtained using this technique.

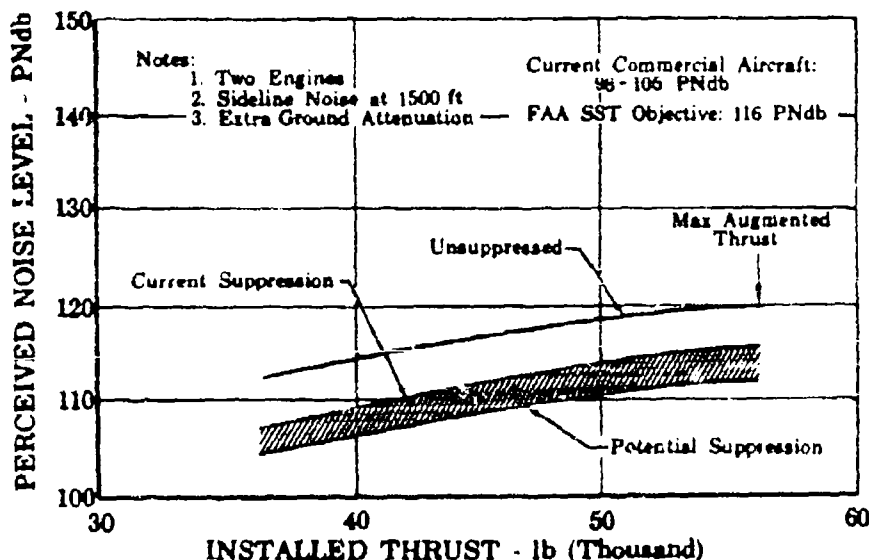


Figure 15. Predicted Turbofan Airport Noise Levels

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Figure 17 shows predicted noise level for Condition 3, the 1 mile approach condition, where acoustic damping and optimum blade-vane spacing reduce fan noise.

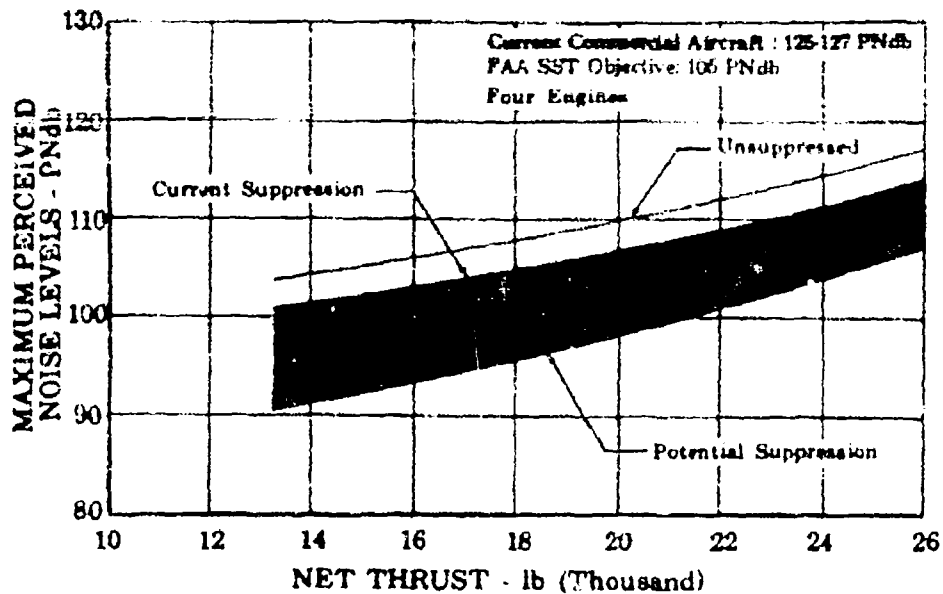


Figure 16. Predicted Turbofan Noise Levels  
at Thrust Cutback After Takeoff

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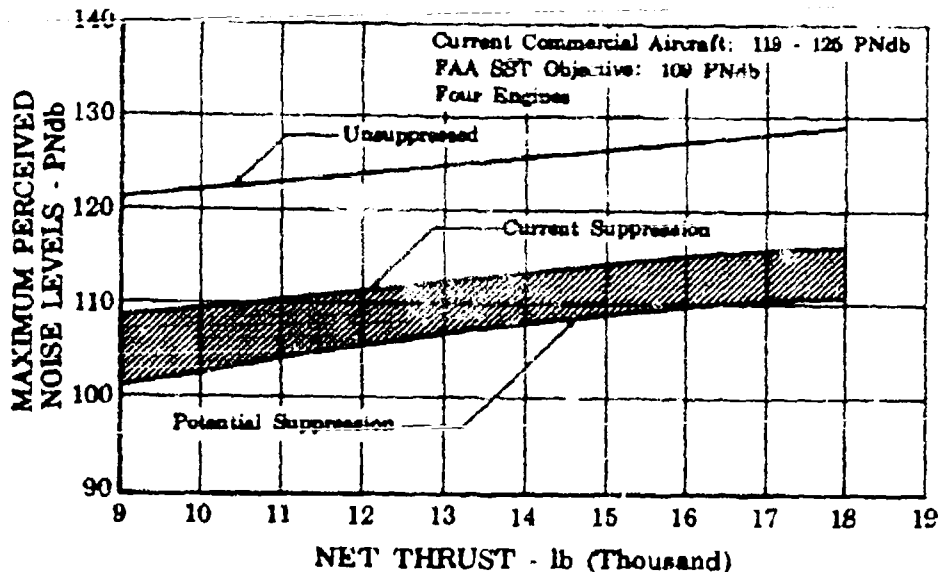


Figure 17. Predicted Turbofan Noise Levels  
at Approach Conditions

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## **B. PHASE III TEST PLAN**

Comprehensive, carefully integrated component and engine test programs have been planned for Phase III to assure that the JTF17 engine program objectives are achieved. Although extensive component testing has been accomplished in Phase II, an accelerated program of component tests has been planned to start in January 1967. These component tests are essential to verify the design of each component, evaluate changes, and determine their performance and durability under varying environmental conditions. To integrate these components and subsystems into a complete engine so that their performance is properly matched can only be accomplished by testing them together in an engine. A total of 8000 hours of engine testing are planned for Phase III.

Ultimately these tests will assure that the 20 engines delivered to the airframe manufacturer for the initial 100-hour flight test program will meet the supersonic transport requirements. Beyond Phase III additional component and engine testing are planned to achieve Engine Certification by the FAA and ensure that the engine will give reliable service and long life in worldwide airline operation. Details of the Test and Certification Plan are given in Volume III, Report E.

### **1. Component Tests**

Component rig tests have preceded the engine test program in Phase II and are planned to continue through the Phase III development. These component tests have been carefully designed to determine the performance of each component under a wide range of operating conditions and to evaluate all the changes required as the development proceeds. Safe operation and durability must also be tested during the component rig tests so that maximum assurance of successful integration into the engine can be given. A summary of the component tests proposed in Phase III follows:

Component Tested	Hours*
Fan	2,300
High Compressor	2,000
Primary Combustor	6,900
Turbine	3,290
Augmentor	3,220
Exhaust System	4,600
Bearings, Seals and Gearbox	54,500
Controls and Accessories	90,000
Total	166,810

\*Note that this component test time does not include engine test time, but represents only component rig time.

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## 2. Engine Tests

Initial engine testing in Phase III will be conducted using the three JTF17 engines available from Phase II-C. These engines will be supplemented so that a total of 12 development JTF17 engines will be used for the Phase III test program. Three additional engines will be used for the engine certification tests in Phase IV. Altogether 8000 hours of engine testing are planned in Phase III to include:

Engine Tests	Hours
Performance testing at sea level and altitude conditions	1,470
Component and subsystem integration testing	2,180
Control system testing	1,120
Inlet compatibility and systems testing	700
Endurance testing	2,005
FTS testing	<u>525</u>
Total	8,000

## 3. Engine/Airframe Compatibility Tests

The development of compatible high performance engine inlet and exhaust systems is very important to achieve the mission requirements of the supersonic transport. Pratt & Whitney Aircraft, working closely with the airframe contractors, is proposing a vigorous and comprehensive program consisting of analytical studies, rig and model tests, and full-scale inlet, exhaust-system, and engine tests. This program is based directly on PWA experience gained in the development of J58 compatibility in the Mach 3+ SR-71 and YF-12 aircraft. This experience showed that it is necessary to integrate the engine inlet and exhaust systems at the earliest possible date. Toward that end, analytical simulations of inlet and engine steady-state and dynamic compatibility and distortion compatibility are already underway in Phase II. The results of these analyses have been coordinated with the airframe contractors and are discussed in Volume III, Report D, of this proposal. In addition, model tests of the exhaust system have been accomplished at subsonic conditions in the wind tunnel with a simulation of the airframe manufacturer's nacelle installation. These tests indicated that engine exhaust system performance should meet the requirements of the supersonic transport. Details of the test results are explained in Volume III, Report D, Section III.

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Engine/airframe compatibility agreements have been coordinated with both airframe manufacturers and are included in the following documents:

**Boeing:**

"Coordinated Inlet/Engine Test Plan" Commercial Supersonic  
Transport Program Report D6A10097-2  
Engine/Airframe Technical Agreement Number D6A10199-1 P&WA

**Lockheed:**

L-2000 Airframe/Engine Compatibility Agreement Exhibit A  
P&WA Interface Control Document  
Lockheed Phase III Proposal Volume IIE, Section 8  
AEDC Inlet/Engine Test Plan

The compatibility of the engine and inlet will be tested in logical sequential steps leading to prototype flight test. Significant test milestones are shown in table 1, below:

Table 1. Engine Inlet Compatibility Testing Proposed Milestones

- |  |            |
|--|------------|
| 1. 0.6-Scale Fan Rig - Distortion generators will be used to simulate patterns obtained from airframe manufacturer testing of model inlet.   | Feb. 1967  |
| 2. Rematched Engine - Testing with distortion generators will be done to evaluate distortion attenuating influence of high compressor. The data will be compared to fan rig distortion test data.  | May 1967   |
| 3. 0.6-Scale Fan Rig - The fan rig will be tested at Willgoos Laboratory with the subsonic diffuser portion of the airframe inlet. These tests will evaluate the subsonic diffuser performance with static pressure gradients imposed by the fan.  | July 1967  |
| 4. 0.6-Scale Fan Rig - Variable vane simulation of high compressor. Test with required back pressures to reproduce circumferential variation of flow determined from the rematched engine. Corroboration of this data will allow development of fan to continue on isolated test basis. Data will also be compared with analytical calculations of distortion effects for corroboration. | July 1967  |
| 5. 0.6-Scale Fan Rig - Willgoos Laboratory testing with the subsonic diffuser portion of the airframe inlet. The July testing will be repeated to evaluate any changes indicated by the earlier test series.   | Sept. 1967 |
| 6. Full Scale Fan - Testing to be done at FRDC altitude facility with variable vane simulation of high compressor. Distortion generators will be used to simulate patterns obtained from airframe manufacturers testing.   | Jan. 1968  |
| 7. JTF17 - Engine will be tested with distortion generators to simulate patterns obtained by airframe manufacturers testing. Steady-state and transient performance will be evaluated.   | Nov. 1967  |

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8. JTF17 - Engine will be tested with the subsonic diffuser, Aug. 1968 flight configuration bleeds, and their controls. Data will be taken at cruise to check performance and preview dynamic compatibility before AEDC testing. Sea level static testing will be done to evaluate performance and distortion effects with a full inlet on the engine. Starting schedules will be optimized. The inlet will be operated in a near choked condition for fan noise attenuation studies.
9. JTF17 - AEDC Test Facility - A ground test engine with the Sept. 1968 supersonic inlet will be tested. Configuration will be a complete engine nacelle system to simulate the free stream inlet.
10. Flight Tests - Propulsion system performance and engine/inlet compatibility will be evaluated during the initial 100-hour flight test program. Flight tests are scheduled to begin as follows:
- |          |               |               |
|----------|---------------|---------------|
| Boeing   | 1st Prototype | December 1969 |
|          | 2nd Prototype | February 1970 |
| Lockheed | 1st Prototype | March 1970    |
|          | 2nd Prototype | June 1970     |

The test program outlined in table 1 will lead up to compatibility tests of the complete propulsion package that are scheduled to be run in the AEDC propulsion wind tunnel in Tullahoma, Tennessee. The details of this program are covered in engine/inlet compatibility test plans that have been coordinated between Pratt & Whitney Aircraft and the two airframe manufacturers. The Pratt & Whitney Aircraft test program is designed to reduce the number of problems that may be encountered during the complete propulsion package compatibility evaluation at AEDC. The time spent in the 16 foot wind tunnel at Tullahoma may then be devoted exclusively to evaluation of those facets of the propulsion system compatibility investigation that can only be handled with realistic external flow.

The ultimate test of the engine/airframe compatibility will begin with the 100-hour flight test of the prototype supersonic transport. The propulsion system performance will be monitored by instrumentation and recording devices. Engine/inlet compatibility and performance and the operation of inlet and engine control systems will be evaluated in various steady-state and transient flight conditions throughout the flight envelope. In addition, extreme and abnormal flight conditions will be simulated in flight. Pratt & Whitney Aircraft will prepare a propulsion system flight test program in coordination with the airframe manufacturer and will provide full support for the flight tests throughout the program.

Throughout the test program, a continuous cross-check between engine test results and analytical simulations will be maintained. This will permit updating of the various simulation system gains and time constants and will ensure that the desired stability and performance requirements are met. Furthermore, this effort will permit an incorporation of the effects of inlet distortion and representation of certain failure modes into the simulations.

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**SECTION IV  
RELATED EXPERIENCE**

**A. GENERAL**

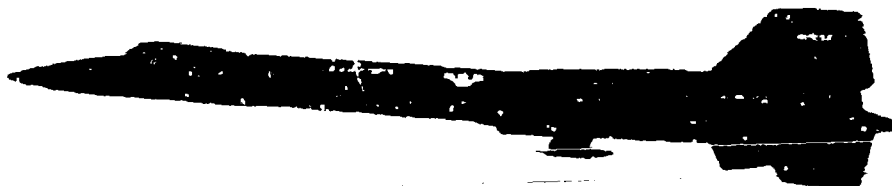
Pratt & Whitney Aircraft offers the supersonic transport program the benefits derived from a unique combination of thirty-nine years meeting airline transport powerplant requirements and of daily operation with high-turbine-temperature turbine engines that meet the requirements of continuous-high-Mach-number-cruise aircraft. The company's airline transport experience dates back to the early days of piston engine operation when its first commercial aircraft engine was delivered to Boeing for the Model 40B single-engine mail and passenger plane in the Spring of 1927. This engine, the "Wasp," received Approved Type Certificate No. 14 from the Department of Commerce on 19 December 1928. Since that time, airline transport aircraft have accumulated more than 200,000,000 engine hours with P&WA piston engines on such well-known airplanes as the Douglas CD-3, DC-4, DC-6, Convair CV-240, CV-340, CV-440, Boeing 247 and 377, Martin M-202 and M-404 aircraft, and Lockheed Lodestar and Model 14 aircraft.

On 15 March 1957, the P&WA JT3C "Turbowasp" received from the Federal Aviation Agency Approved Type Certificate No. 290, and became the first U.S. turbojet in airline transport service, powering the initial versions of the Boeing 707 and Douglas DC-8 aircraft. Since these aircraft went into service in November 1958, over 40,000,000 engine hours of airline service have been accumulated on P&WA turbojet and turbofan powered aircraft. Pratt & Whitney Aircraft engines are currently accumulating time and experience in airline service at the rate of approximately 1 million engine hours per month and this rate of accumulation should double by approximately December, 1968 as the number of aircraft in service doubles by that date. It is estimated that P&WA commercial turbine transport experience will total 175 million engine hours by the 1974 time period in which initial U.S. SST passenger service is anticipated.

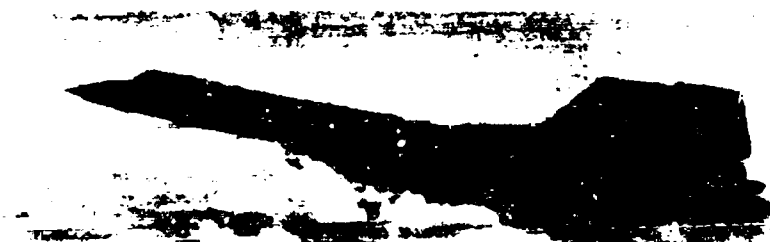
On 25 May 1953, the USAF F100 became the first aircraft to achieve sustained supersonic speed in level flight, powered by the P&WA J57 afterburning turbojet. Since this first sustained supersonic flight, Pratt & Whitney Aircraft has accumulated approximately a quarter of a million engine hours in supersonic operation. For the SST, the most significant of this experience is that obtained with the FRDC-developed J58 in the XF-12 and SR-71 aircraft, which have flown more than a million miles above Mach 3. These aircraft and the J58 engine are shown in figures 18 and 19. Aircraft powered by J58 engines, operating continuously at over 2000°F turbine temperature, accumulate daily, on the average, more flight time above Mach 3 than the total free world experience at Mach 3 in all other aircraft combined. With the introduction of the SR-71 into military service, additional experience which is being gained concurrently with the development of the JTF17 SST engine adds to the knowledge already in hand. This Florida Research and Development Center experience and technology will contribute directly to the timely and successful development of the supersonic transport engine.

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Lockheed YF-12A



Lockheed SR-71

Figure 18. Pratt & Whitney Aircraft J58-  
Powered Aircraft

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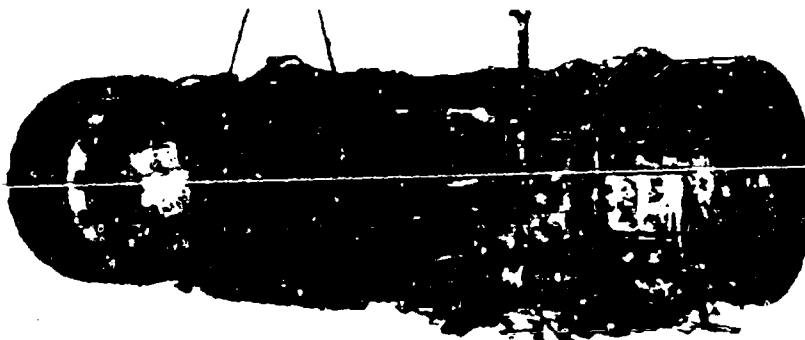


Figure 19. Pratt & Whitney Aircraft J58 Engine FE 42662

#### B. AIRLINE TRANSPORT EXPERIENCE

##### 1. Product Support in 22 Countries

Pratt & Whitney Aircraft engines are now operated by over 200 airlines throughout the world. The continuing accumulation of airline operational experience means that Pratt & Whitney Aircraft's Product Support and Engineering organizations will be gaining a knowledge in many areas that are important to the SST Program. Among the most important of these are:

- a. Service Department Cooperation with the airline operators to establish improved methods and techniques for maintenance and overhaul of large commercial turbine type engines.  
(Example - Development of engine maintenance reliability programs under FAA advisory Circular AC 120-17, dated 31 December, 1964, "Handbook for Maintenance Control by Reliability Methods.")

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- b. Flight Operations Engineering Department working with airline operating and maintenance personnel to develop improved methods of monitoring engine operation as an aid in early detection of maintenance problems. (Example - The Study and development of Aircraft Integrated Data System, known as AIDS, to determine the most efficient means of integration of data recording and processing for use in maintenance and operation analysis and display of information for the flight crew and for ground personnel on the mechanical condition of airplane systems, including the propulsion system.)
- c. Spare Parts Department cooperating with airline maintenance and supply personnel to improve methods of forecasting overhaul and maintenance parts requirements. (Example - Investigation of inventory management improvements through use of computer techniques.)

The Pratt & Whitney Aircraft Product Support organization has representatives in more than 200 locations in 22 countries throughout the world. The location of the more than 60 PWA Field Service Representatives stationed outside North America is shown on the map, figure 20.

The level of experience of the top 11 supervisory people in the Product Support organization averages 29 years. The average level of experience of the more than 320 Service representatives working with airline operators throughout the world is 16 years.

One of the several ways by which the continuing accumulation of airline service on Pratt & Whitney Aircraft engines and the accumulation of continued experience by the Product Support organization is focused on airline problems is through a biannual jet engine conference at Pratt & Whitney Aircraft. These meetings are attended by engineering and maintenance personnel from the staffs of Pratt & Whitney Aircraft's airline customers, by Pratt & Whitney Aircraft's technical service representatives and by the home office Product Support and engineering staffs of Pratt & Whitney Aircraft. These meetings have been conducted since 1959. At the next meeting, scheduled to be held in the fall of 1966, approximately 200 airline representatives are expected to be in attendance.

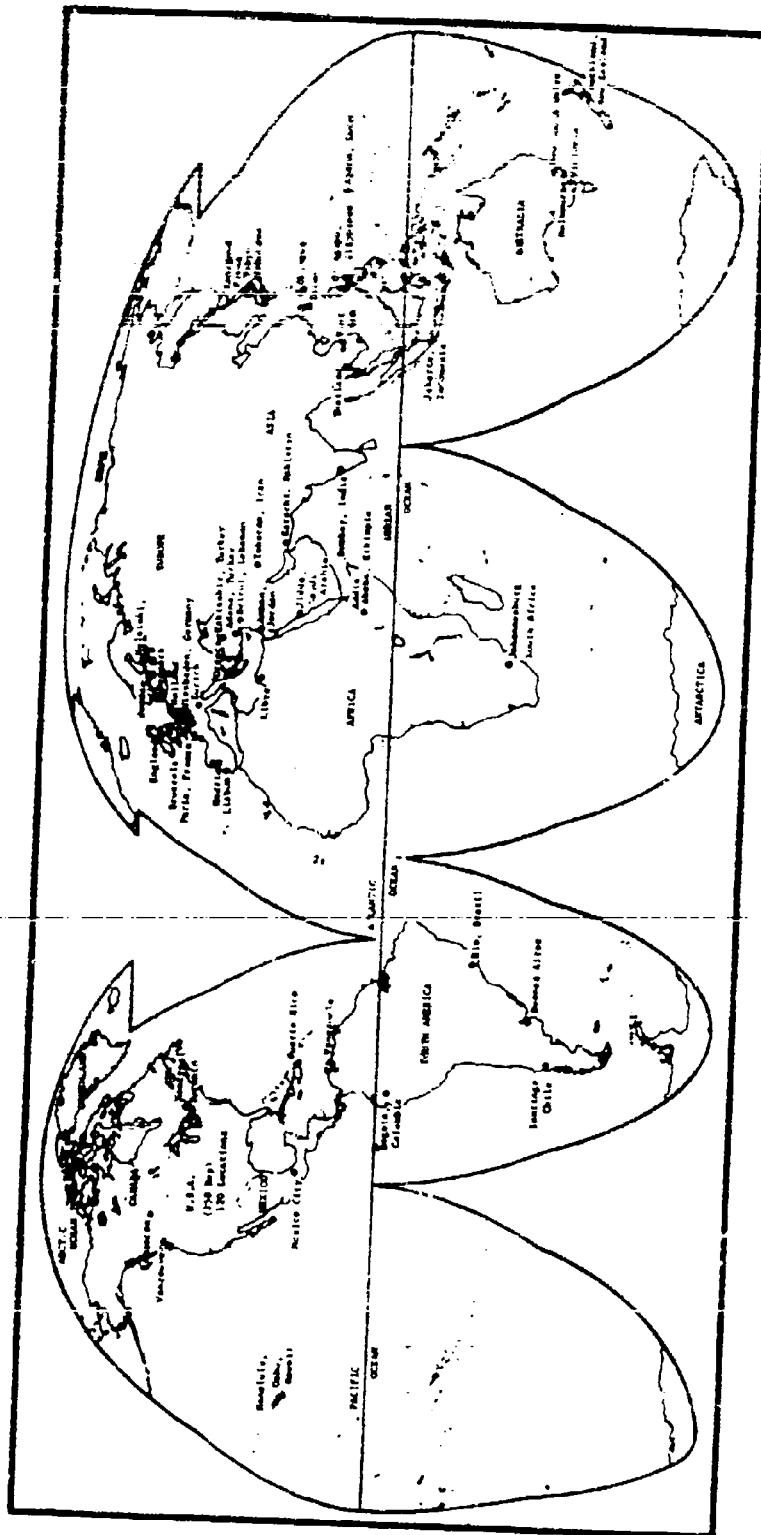
At these meetings the Product Support and Engineering Development staffs on the various commercial engine projects prepare formal briefings on current airline engine problems, based on questions and suggestions from the airlines themselves. Ample opportunity is given for airline representatives to ask questions and to consult with one another on matters of mutual interest. This forum will continue to be an excellent medium for continuing close communications between the airlines and the Pratt & Whitney Aircraft Product Support and Engineering staffs. All of these future Jet Engine Conferences will be attended by representatives from the JTF17 Program Management so that solutions to airline problems can be incorporated in the SST engine.

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Figure 20. International Location of Field Service Representatives

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## **2. Understanding Airline Needs**

An even more important result of this very extensive background of close cooperation with the airline operators has been the acquisition of a thorough understanding of the specific needs of the commercial operator. In many ways these differ from those of the military operator. Among the most important of these specific airline requirements are:

1. Engine reliability in terms of low "in-flight shutdown" and "unscheduled removal" rates. Table 2 shows comparative reliability records from CAB records for P&WA turbojet and turbofan engines and for those of a major competitor for the period 1960-1965. As may be noted from the comparative figures in the table, the rate of unscheduled engine removal per 1000 hours for the P&WA engines listed was less than one-half the unscheduled removal rate for competitive engines.
2. Engine durability in terms of high TBO or engine inspection period and long parts life. Table IV-2 shows comparative TBO growth records for P&WA and competitive engines for the period and long parts life. Table 3 shows comparative TBO growth records for P&WA and competitive engines for the than on those of the competitor's engines. Actually the P&WA JT3D engine now has an FAA-approved TBO of 8500 hours.
3. The need for adequate growth of engine size, cycle, and performance as may be necessary to produce a more useful and more profitable airline transport airplane. Perhaps the most outstanding example is the development and introduction of the 17,000- to 18,000-lb thrust turbofan engine into commercial airline service in 1961. The use of this engine resulted in an improvement of approximately 20% in airplane miles/lb of fuel; airplanes powered by this engine have set the world standard for reliable, economical, long range transport aircraft.
4. The need for meeting commitments on both schedule and performance in order that new airline type transports may be delivered to the operator on time and with the engine performance that the airframe manufacturer and the operator expect. Table 4 shows how Pratt & Whitney Aircraft met previous commitments in terms of initial delivery, engine weight, engine thrust, and cruising fuel consumption.

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Table 2. Unscheduled Engine Removals

Year	Engine Chargeable Premature Removals Per 1000 Hours			
	Pratt & Whitney Aircraft		Competitor "A"	
	JT3 Turbojet	JT4 Turbojet	JT3D Turbofan	Turbofan
1960	0.12	0.16	--	--
1961	0.33	0.26	0.68	2.0
1962	0.34	0.45	0.38	0.85
1963	0.40	0.36	0.27	0.99
1964	0.35	0.29	0.21	0.59
1965	0.38	0.24	0.19	0.45

Table 3. TBO Growth

Year Ending 31 December	Pratt & Whitney Aircraft			
	Pratt & Whitney Aircraft		Competitor "A"	
	JT3 Turbojet	JT4 Turbojet	JT3D Turbofan	Turbofan
1960	1000	1400	--	--
1961	1600	2000	1200	--
1962	2400	3400	2000	1750
1963	3800	4800	2900	2000
1964	4600	6000	4500	2000
1965	5800	7000	6700	2700

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Table 4. Pratt & Whitney Aircraft Record in Meeting Commitments  
Commercial Engine

Engine Model	Initial Delivery		Engine Weight		T.O. Thrust		Cruise ISEFC	
	As Ordered	When Delivered	As Ordered	When Delivered	As Ordered	When Delivered	30-35,000 ft Alt M.8 As Ordered	When Delivered
JT3C	Apr 1958	Apr 1958	4350	4234	13,000	13,000	0.91	0.91
JT4A	Jun 1959	Apr 1959	5570	5020	15,800	15,800	0.88	0.87
JT3D	Aug 1960	Sep 1960*	4025	4025	17,000	17,000	0.78	0.78
JT8D	Feb 1963	Feb 1963	2734	2994	14,000	14,000	0.80	0.79

\*One month delay due to labor strike idling more than 50% of production personnel.

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C. SUPERSONIC CRUISE EXPERIENCE

1. System Integration

The supersonic aircraft propulsion system requires the utmost care in its integration into the total airframe system. The kind of close technical working relationship between the engine and airframe contractors, essential to the success of the supersonic transport, is exemplified by the approach taken by the Florida Research and Development Center in the J58 program. Of particular importance in this program was the early technical integration of the engine and airframe inlet duct. In light of this experience, P&WA and the airframe manufacturer will pursue on the SST program from the earliest possible date, a vigorous, coordinated, cooperative program consisting of analytical studies, dynamic mathematical simulations, rig and model tests and full-scale inlet and engine tests. To avoid the possibility of delays in the flight test program and the complete engine nacelle test program at AEDC, initial compatibility tests of both the inlet and exhaust systems as well as various other engine/airframe propulsion system components will be conducted by compressor and other component rigs, by windtunnel model simulations, and by experimental development engines. The United Aircraft Corporation windtunnel facilities were used extensively in achieving inlet and exhaust system compatibility for the J58, and will be used similarly to assist in the integration of the JTF17 into the SST aircraft.

In order not to delay flight testing throughout the flight envelope of a high Mach number airplane, the J58/YF12-SR71 program has shown the necessity of a fast reaction for flight test revealed problems in both the airframe and engine. The J58/YF12-SR71 high Mach number cruise airplanes were the first in the free world to face these conditions, and many unforeseen problems were uncovered in both the airframe and the engine during flight testing. Most of these were of rapid transient nature which could not be completely duplicated beforehand in ground based facilities. However, in a number of cases, after the problem was understood, test facilities were modified to more closely duplicate the conditions and solutions were then developed on the ground without jeopardizing the flight test airplanes. The experience gained with the J58 will ensure that a large number of these problems will be avoided in the supersonic transport JTF17 engine. However, there will undoubtedly be mechanical as well as aerodynamic and thermodynamic problems peculiar to a new engine/airframe combination that will be uncovered by flight test. In order to cope with this situation in a timely fashion, a very fast reporting and engineering reaction system must exist. This requires engine project engineers at the site during flight testing, and a free and candid exchange of information between the airframe and engine engineering organizations, to obtain quick and satisfactory solutions to flight-test-revealed problems.

2. Supersonic Cruise Development Techniques

The success of the J58 engine in its hostile environment is due in no small part to over 75,000 hours of component testing in the appropriate environment and to over 8000 hours of full-scale engine testing in P&WA's high Mach number altitude test facilities. Among the many engine problems

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revealed and solved during this environmental testing were first-stage compressor blade airfoil vibration due to aerodynamic flutter at some high Mach number flight conditions, fuel control system malfunctions resulting from temperature differentials, and compressor disk distortion because of rapid temperature changes. The great importance of this high Mach number environmental testing has been reflected in the proposed Phase III test program.

Computer methods have been developed that simulate the dynamic performance of the engine and its inlet well enough so that the proper control modes can be selected in the design stage rather than after flight test. The analog computer shown in figure 21 has been used to provide dynamic simulation of supersonic cruise propulsion systems. The air inlet performance, the inlet control, the engine performance, the engine control, and the complete fuel system are all simulated by this computer, so that the behavior of the propulsion system as a whole can be observed over the full range of flight conditions, and so that the effects of malfunctions can be analyzed. This kind of simulation is prerequisite to proper system design. It continues to be a valuable diagnostic tool throughout the development and flight test program, when measured component performance can be substituted in the computer input for the originally estimated values. Dynamic simulation is thus particularly valuable in simulating flight test problems and exploring various means of solution through control system changes or adjustments prior to actual flight testing of such changes.



Figure 21. JTF17 Dynamic Simulator

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The high Mach number continuous cruise environment calls for the application of high temperature materials well forward into the compressor section. At the same time, the emphasis on better over-all thrust-to-weight ratios calls for use of materials which have better strength-to-weight ratios, particularly at the elevated temperatures involved. For continuous supersonic cruise operation, materials different from those used on subsonic engines are required for a given part, and these materials are generally more expensive and more difficult to machine. Furthermore, more rigorous quality control methods must be employed to assure reproducibility in quantity with predictable metallurgical characteristics. Ordinary sea-level testing does not subject these new materials to their most severe environment, and endurance testing must now be conducted over the full range of flight conditions. Where ordinary sea-level endurance tests were adequate for the subsonic jet or fan engine, the supersonic cruise engine, in contrast, must be operated in a rather sophisticated facility, such as that shown in figure 22, to simulate transonic and supersonic conditions.



Figure 22. FRDC High Mach Number Laboratory

FC 13269

### 3. High Temperature Experience

The development of the J58 engine has provided solutions to some of the most challenging metallurgical development problems ever encountered. Because of unprecedented levels of operating temperatures and stresses for hardware components throughout the engine, nickel base super-alloys which had been previously used only for turbine blades, now were needed for large disk forgings, ring forgings, and sheet components. Extensive alloy development, modification, and process development were accom-

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pushed to meet hardware requirements. In addition to this nickel base alloy development program, titanium technology was extended to allow compressor blades to operate under the most demanding conditions to which titanium blades have ever been subjected. Titanium alloys being used in the JTF17 are the same as those used in current P&WA commercial engines and in the J58 engine. Finally, advanced coating systems were developed to increase the life of components by protecting components against severe environmental effects.

Astroloy turbine and compressor disks have performed most successfully in the J58 engine. This experience has demonstrated the outstanding capability of the alloy and substantiates its suitability for turbine disk application for the JTF17 engine. Structurally, the 1st-stage turbine disk is almost identical to the J58 engine 1st-stage turbine disk in size, shape, and manufacturing technique. A comparison of the J58 and JTF17 engine turbine disks is shown in figure 23.

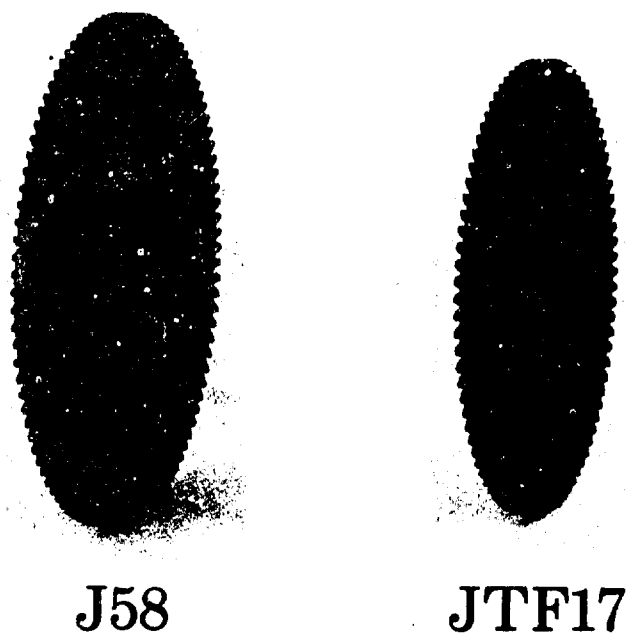


Figure 23. Turbine Disk Comparison

FD 17648

Similarly, as shown in figure 24, the JTF17 1st-stage turbine blade bears a close resemblance to the J58. However, to ensure the long life necessary in a commercial engine, the JTF17 engine blade metal temperature is 150°F lower at cruise conditions than that for the J58 engine. Development engine test time on the J58 at maximum rated turbine inlet temperature is over 10,000 hours with 500 hours at or above 2100°F. This is in addition to substantial service experience.

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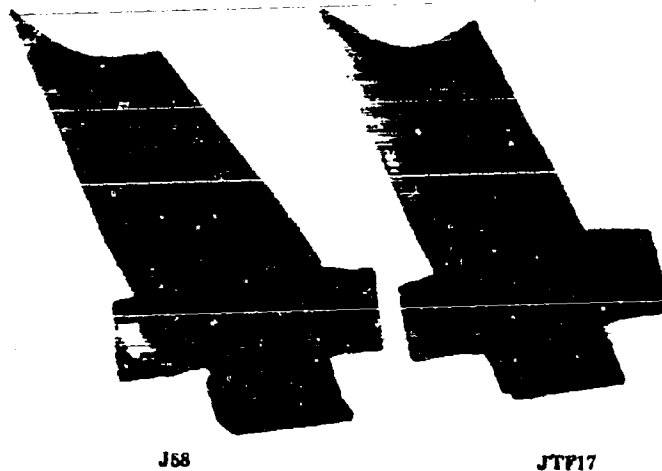


Figure 24. 1st-Stage Turbine Blade Comparison

FD 16883

#### 4. Specialized Manufacturing Requirements

Pratt & Whitney Aircraft Experimental and Production Manufacturing departments within the Connecticut Operations and Florida Research and Development Center have demonstrated the ability to research and develop new manufacturing techniques and apply them to the production of engine parts under full process control. As a result of the J58 experimental and production program special techniques such as the manufacture of disk, blades, and cases from high temperature alloys have been acquired. Aircraft quality high pressure tube assemblies with integral end fittings have been developed and applied to production engines. Metal removal methods, such as electrochemical machining, have been pioneered by Pratt & Whitney Aircraft, the world's largest user of this equipment. Both Experimental Development departments and Production Manufacturing departments now have extensive experience in production of parts for jet engines capable of continuous operation at SST cruise conditions.

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**SECTION V**  
**RESOURCES**

**A. FACILITIES**

As the result of the J58 development and production programs, the Manufacturing facilities of Connecticut Operations and Florida Research and Development Center are fully experienced in and equipped for the special techniques essential to the production of parts for engine intended for continuous supersonic operation. The Manufacturing facilities of FPDC require additions only as necessary to provide for the larger physical dimensions of some of the JTF17 parts. Connecticut Operations production facilities, where the production J58 engines are produced, have no equal in the field of aircraft jet engine manufacture. Pratt & Whitney Aircraft has developed a family of 2500 vendors who fully understand PWA's specifications and who have proved to be capable of producing high-quality aircraft engine parts.

All of the facilities required for the JTF17 program exist now or will be acquired or placed in use during Phase III. No additional facilities are required for Phase IV; those acquired during Phase III will continue to be used. All of the Connecticut manufacturing and test facilities described in Volume V, Report B, will be in existence and can be used for Phase V of the SST Program. Phases III and IV of the SST Program will be carried on principally at the Florida Research and Development Center, with some specialized testing and support provided by the Connecticut facilities. Production of JTF17 engines in Phase V will be accomplished at the Connecticut plants, with development continuing in Florida.

Four plants, all company-owned and in Connecticut, will be used for production engine deliveries for Phase V of the SST Program. They contain 7,897,600 square feet of floor space and approximately 4000 production machine tools.

Florida Research and Development Center facilities now include 1,150,000 square feet of floor space. Manufacturing, assembly, and inspection tools number 473 major items. The turbojet test areas contain 54 stands with capabilities ranging from full-scale engine and rig testing to small component calibration. Supporting these activities are a Materials Development Laboratory, a Computing Laboratory, and an Instrument Laboratory. For Phase III and IV of the SST Program, the floor space will be expanded by 96,000 square feet. A limited number of major manufacturing tools will be added and eight new test stands will be constructed.

The Computer Laboratory capabilities are now in process of improvement by replacement of several existing IBM systems with newer models. The Connecticut facilities to be used for Phases III and IV include the Andrew Willgoos Turbine Laboratory, consisting of 14 test stands; the United Aircraft Research Laboratories Wind Tunnel; and the Advanced Materials Development Laboratory.

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The facilities currently available to the research and development team at FRDC represent an investment in excess of \$90,000,000, more than half of which is company owned. To conduct Phase III of the supersonic transport program, United Aircraft will invest approximately \$30 million in additional facilities, 75% of which will be to increase engine and component test capability.

These Florida test facilities provide an on-line data acquisition, reduction, and processing system that automatically transmits key engine performance parameters to the test engineer within 2 minutes of the time they were recorded. This allows the test engineer to immediately diagnose trouble and make the necessary corrections in order to attain test objectives as quickly as possible. Also, the amount of useful data which can be quickly and accurately acquired and reduced provides the engineer with complete information of the internal and external operating characteristics of the engine. This results in a significant reduction of the number of tests required to obtain given performance points and enables the engineer to run a broader test program in a given time period.

FRDC has complete computer systems compatibility with the airframe manufacturers through the use of IBM 360 and 7090 computers and Fortran programming language.

The instrumentation facilities have been developed to provide field support of high Mach number flight testing, and for the specialized development of high temperature instrumentation systems required by the J58 development program.

#### B. MANPOWER

The Florida Research and Development Center over-all manpower requirements during the Phase III period are forecast to peak in the year 1969 with only a slight increase over the current 1966 level. The additional manpower of approximately 1600 people estimated to be needed in this period is significantly less than that added in the period from mid-1959 to mid-1962, when the total FRDC employment was increased from 2300 to 6100. (See figure 25.)

The increase in technical personnel required to continue the SST engine development will be obtained by transfers from current programs, which will be decreasing, as well as by adding approximately 220 new technical employees by 1968. The rate of growth to meet this figure is less than that experienced in the past five years. (See figure 26.)

Pratt & Whitney Aircraft's production manpower requirements are currently increasing and are projected to peak at about 39,000 people in 1969. This projected manpower is more than adequate to accommodate the planned production of the JTF17 in the required time period. (See figure 27.)

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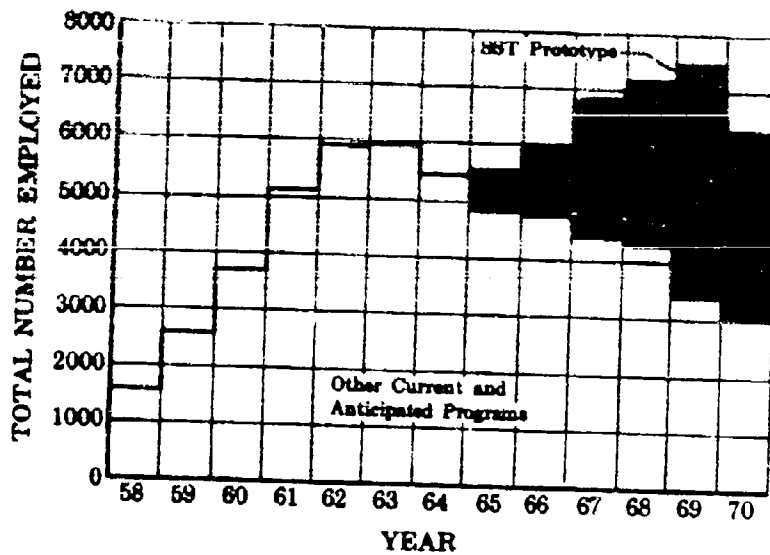


Figure 25. FRDC Manpower Requirements

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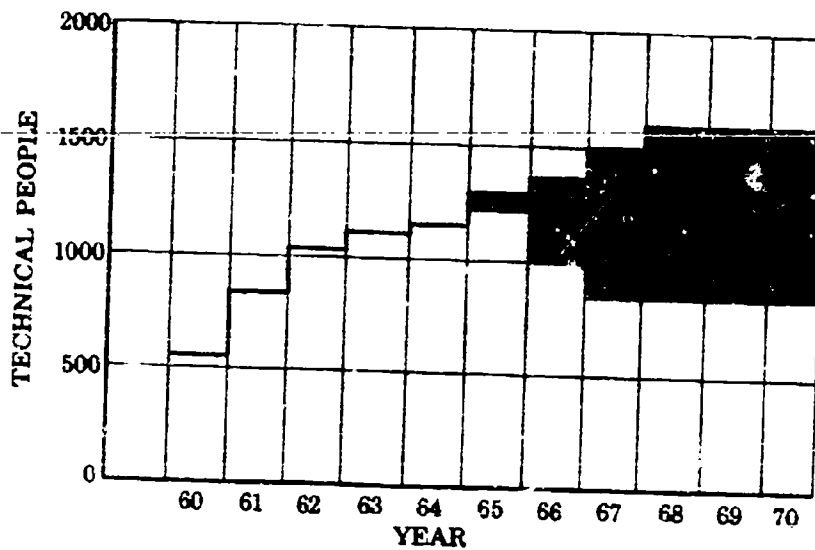


Figure 26. FRDC Technical Manpower

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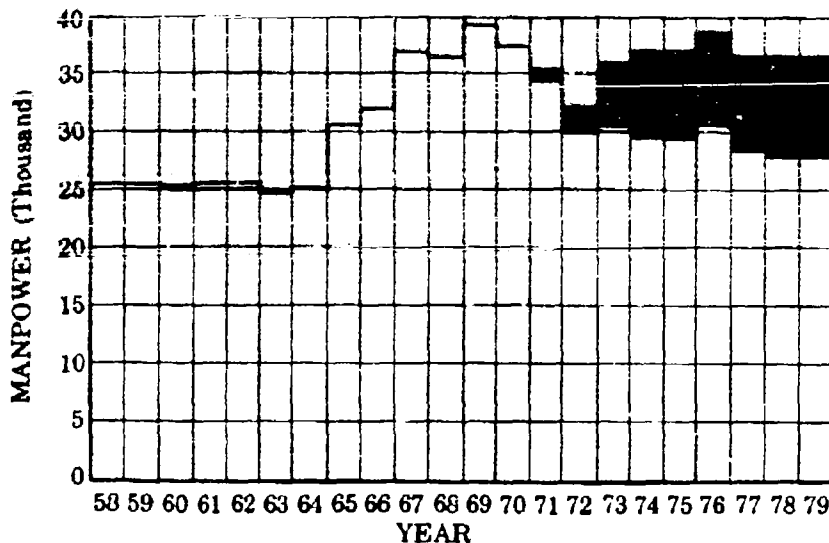


Figure 27. East Hartford Total Manpower

FD 16525

#### C. FINANCIAL

Assurance of financial resources of United Aircraft Corporation (parent corporation of the Pratt & Whitney Aircraft Division) to meet the requirements for the 4-year Phase III SST powerplant program is provided by a review of its record of gross sales and before income tax earnings for the past four years (1962, 1963, 1964, and 1965).

Four Year Total Gross Sales	\$5,107,200,000
Four Year Total Earnings Before Income Tax	219,230,000

United Aircraft has financed without contractual support, research and development programs that have cost in excess of \$225,000,000 over the past 8-year period.

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**SECTION VI**  
**COSTS**

**A. ESTIMATES**

The overall cost estimates listed in the Introduction of this Volume I have been prepared on the basis requested in the FAA's 30 June 1966 Request for Proposal. In accordance with the FAA's instructions, the production engine unit cost estimate of \$1.21 million does not include any provision for recoupment of either the Government's or the Company's share of the pre-aircraft-certification engine development costs.

The production unit cost estimate for the JTF17 engine also reflects the savings that will result from the constant effort of the Connecticut Operations manufacturing department to reduce costs through the use of advanced techniques and equipment. Typical of this effort is the constantly increasing use of numerically-controlled machines in manufacturing operations. Pratt & Whitney Aircraft now has over 100 numerically-controlled jig borers, horizontal boring machines, milling machines, drills, turret lathes, jig grinders and gear shapers. Figure 28 shows a 5-axis continuous path numerically controlled milling machine in operation.

**B. RELATIONSHIP OF ENGINE PROGRAM COSTS TO OPERATING COSTS AND PROFITABILITY**

In considering the economics of the SST airplane, the effect of the engine on profitability must be assessed in terms of its contribution to airplane Direct Operating Cost (DOC). Table 5 gives a breakdown of the major engine-affected DOC items as percent of the total airplane DOC for the FAA Economic Model Ground Rules average international distance of 1980 statute miles. From the above basic data the following trade factors can be calculated for the effect on DOC of changes in fuel consumption and development cost estimate:

- 1% change in airplane DOC results from a 2.6% change in SFC
- 1% change in airplane DOC results from a 50% change in development cost estimate

From this it is apparent that engine performance in terms of TSFC is the most important of the engine-affected items, far outweighing engine development program costs in its effect on airplane operating costs and thus on profitability. A comparison of the trade factors for fuel consumption and development cost indicates that a vigorous and extensive development program can be justified to achieve or surpass the specification performance goals.

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Table 5. Breakdown of Direct Operating Costs for  
Typical SST Design

Calculated in Accordance With FAA Economic Model Ground Rules for  
Average International Distance of 1980 Statute Miles

	Total Airplane DOC, %
Aircraft and Crew Costs	42
Fuel and Oil	38
Engine Depreciation, Insurance and Development Royalty	8.5
Engine Maintenance, Material, Labor and Applied Burden	11.5



Figure 28. 5-Axis Continuous Path Numerical  
Control Milling Machine

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